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MEMOIRS

OF THE

CARNEGIE MUSEUM

VOL. IV

(1906-1911)

W. J. HOLLAND, *Editor*.

PITTSBURGH

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PREFATORY NOTE.

The publication of the Seventh Number of the Memoirs assigned to the Fourth Volume of the series has been selected by the Editor as making a suitable point at which to close the volume. While the number of pages of letter-press is less than in some preceding volumes, the number of plates is twice as great as in any of them, and to hold the volume open for further additions would result in making the book too bulky and inconvenient to handle.

Volume III of the Memoirs has not at this date been brought to a conclusion. The Monograph upon the Osteology of the Chalicotheriidæ, long in process of preparation by the Editor, has not yet been entirely completed, but it is confidently expected that before the end of the present calendar year it will have been issued from the press.

Volume V of the Memoirs will open with a monographic paper upon the fresh-water fishes of British Guiana from the pen of Dean C. H. Eigenmann. It is possible that this monograph with the accompanying plates and maps may be found to supply material enough in itself to constitute Volume V, which, in that event, will consist of a single number.

Volume VI of the Memoirs will open with a paper upon the Fossil Fishes from the Jurassic of Solenhofen now in preparation by Dr. Charles R. Eastman.

April 15, 1911. W. J. HOLLAND.

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ERRATA AND CORRIGENDA.

Page 227, lines 3 and 4 from top, *for* "especially in the latter" *read* "especially the latter."

Page 229, line 8 from top, *for* "vertebra," *read* "vertebræ."

Page 237 for legend of upper figure *read* "Fig. 32. Trapezium (right side) of *D. superbus*. Nat. size. 1, dorsal view; 2, radial view; 3, superior view; 4, posterior view; 5, ulnar view; 6, inferior view."

Page 237, for legend of lower figure *read* "Fig. 33. Magnum (left side) of *D. superbus*. Nat. size. 1, dorsal view; 2, ulnar view; 3, radial view; 4, palmar view; 5, inferior view; 6, superior view."

Page 251, last line, *for* "fibular" *read* "tibial."

Page 255, line 3 from bottom, *dele* "the."

Page 257, line 19 from bottom, *for* "Oligocence," *read* "Oligocene."

Page 260, line 3 from top, *for* "Paradaphœnus" *read* "Paradaphænus."

Page 261, line 9, *for* "Cynadesmus" *read* "Cynodesmus."

Page 263, last line, *for* "posteriar" *read* "posterior."

Page 277, lines 9 and 10 from top, *for* "Brachygale" *read* "Sthenictis."

Page 278, line 5 from the bottom, *for* "Melivoradon" *read* "Melivorodon."

Page 278, line 2 from bottom, *for* "Brachygale" *read* "Sthenictis."

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MEMOIRS

OF THE

CARNEGIE MUSEUM.

VOL. IV. NO. 1.

W. J. HOLLAND, EDITOR.

EARLY CHINESE WRITING

BY FRANK H. CHALFANT.

PITTSBURGH.

PUBLISHED BY THE AUTHORITY OF THE BOARD OF TRUSTEES OF THE

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MEMOIRS

OF THE

CARNEGIE MUSEUM.

VOL. IV. NO. 1.

EARLY CHINESE WRITING.

By Rev. Frank H. Chalfant.

I. Illustrations of Early Writing Derived from Ancient Inscriptions.
II. Notes upon the "Shuo Wên."
III. The Royal Edict Confirming the Domain of San.
IV. Ancient Inscriptions upon Bone and Tortoise Shell.

Prefatory Note.

The Rev. Frank H. Chalfant, who for nineteen years has been a missionary in the Province of Shantung, China, has devoted much time to the study of Chinese archæology, and more particularly to the ancient Chinese writings which tend to throw light upon the origin of the present written and printed symbols. Upon the occasion of a recent visit to the United States the writer induced Mr. Chalfant to put into shape for publication the following memoir upon which he had for several years been laboring at moments of leisure. It embodies a large amount of interesting and curious information collated from Chinese sources, which, though in part known to students of the Chinese language, has not been put into a form easily accessible to philologists. Mr. Chalfant in his memoir has not confined himself to material known hitherto, but has embodied in his paper the results of original observations made by him upon archæological material acquired by himself and others from the Province of Honan, consisting of inscriptions of great antiquity upon bone and tortoise-shell. This material when further examined promises to yield valuable results. For the first time, so far as is known to the writer, a tentative translation of the edict designated by Mr. Chalfant as "The San Edict" is given. This is a legal paper of undoubted antiquity, going back at least to 1000 B. C.

Mr. Chalfant has with great patience and skill written with his own hand the characters which are employed in the text and accompanying plates, which have been carefully reproduced by photogravure.

W. J. Holland,
Director of the Carnegie Museum.

I. ILLUSTRATIONS OF EARLY WRITING DERIVED FROM ANCIENT INSCRIPTIONS.

The study of alphabetic or syllabic languages readily resolves itself into two branches: orthography, which concerns the correct use of letters and syllables and the history of these phonetic signs; and etymology, which deals with the derivation of words and their successive changes in meaning. The fact that the letters and syllables as writing-signs have only a phonetic value, and are used without reference to their original and inherent significance, causes a distinct demarcation between the two branches of philology just mentioned. For example, it is well known that our letter A was originally an ox's head and signified that animal, but it does not follow that every word containing the letter A must needs have some connection with an ox.

Turning now to ideographic languages, the case is very different. Here the word or symbol is in itself significant of the meaning which it bears. The A still means "ox," when it occurs alone or in combination, and the student must determine what relation the accepted meaning of the symbol has to that of the primitive ideogram.

The Chinese language is in the main ideographic, with a tendency to syllabism owing to the infusion of certain classes of signs called "radicals" and "phonetics." Where the "phonetic" is purely such, the student need not attempt to reconcile the accepted meaning of the complex symbol with that of the phonetic sign, the specific meaning of which may be quite foreign to that of the complex symbol in which the phonetic occurs.[1] At the same time it must be remembered that the introduction of the "phonetic" was at one time a new idea to the Chinese. Once appreciated, they applied it widely, and where a writer discovered in an old symbol some semblance of a newly recognized phonetic, he forthwith altered it to suit the phonetic scheme. This recalls the old-time rage in Europe for Latin derivations, which led to the Latinizing of familiar Anglo-Saxon words, *e. g.*, *tongue* from A. S. "tung."

In many instances the Chinese resorted to punning in order to bring a certain symbol into the phoneticized class. Such may have been the case in the symbol

[1] An example of this is shown in the sign 囿 *yu* = "park." The phonetic 有 *yu* means "have," and here has only a phonetic value.

蟲 *chung* = "grasshopper." This is contracted from 蠶 which is made up of 衆 *chung* = "multitude" and 虫 "insects." This "multitudinous insect" happened to be called "*chung*," so that in selecting a phonetic sign "chung" a pun was apparently made by adopting the symbol 衆 = "multitude." Without doubt many phonetics add to the meaning of the symbol in which they occur. These we may call "significant phonetics" to distinguish them from such as are used without reference to their inherent meaning.

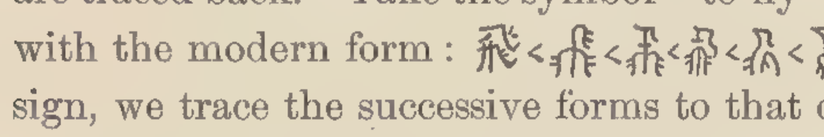
It thus appears that in the Chinese language orthography and etymology overlap. The key to the meaning of a sign lies in the ideogram itself. When we study the changes in the form of the symbols we also learn the history of their varied meanings. Besides the "phonetic" we find another class of affixed signs intended to aid the reader in distinguishing the nature of the symbols. These have unfortunately been called "radicals,"[2] whereas "determinatives" or "classifiers" would have been better. They determine the nature, class, or material of the symbol to which they are attached. Thus words of feeling will likely appear with the "heart (心 or 忄) radical" affixed. The names of wooden things contain the sign for "tree" (木). The names of metallic objects are accompanied by the "metal (金) radical."[3] There are now two hundred and fourteen radicals, reduced from the five hundred and forty "primitives" or "classifiers" of the Shuo Wên, A. D. 120, (see *infra*). Many of them designate incongruous groups of symbols not mutually related, and often utterly at variance with the meaning of the radical. This has happened through the accidental coincidence of forms in many symbols which have been evolved from widely dissimilar roots. A marked example of this incongruity is the group of symbols under Rad. 44 (尸 "corpse"), very few of which have any relation to *death*.

Familiarity with Chinese modes of thought, methods of work, and social customs aids much in determining the significance of certain old signs. The history of ancient institutions which have now passed away, or been modified, also helps in the same manner. For example, it is a tradition among the Chinese that the East Palace was the hall of audience and place for administering the laws. When we find an old symbol for "judge" composed of the elements "east" (東) and "speak" (言) we see an appropriateness in the combination from the ancient custom of "judging" in the "*East*" Palace.[4]

[2] The Chinese name is 字部 *tsï-pu* "word-class" or "classifier." The colloquial term is 字母 *tsï mu* "word mother."

[3] This is usually termed the "gold radical." It means metal of any kind, and "gold" only by its preëminence as a metal.

[4] The edict of Wu Wang (?), referred to elsewhere as the "San Edict," was "given in the East Audience Hall."

Care must be taken not to overvalue fantastic and distorted symbols, due to illiteracy or intentional alteration. Sometimes a pictograph occurs where a descriptive ideogram already existed for the same object. Thus in a certain old inscription the picture [5] occurs for the descriptive symbol, (modern 雞 *ki* "chicken"), "bird" 隹 with "claws" 爫 and "feathers," 彡. While the latter contains nothing characteristic of a chicken as compared with other birds, still it is descriptive and not pictorial. The picture of the bird answers the purpose of conveying thought just as well as the descriptive symbol, but it would be wrong to infer that the two are identical as pictographs. They are merely two separate signs for the same idea. Possibly the writer in this case was not familiar with the existing sign, and so drew a picture of a chicken which answered just as well, and was quite in keeping with the genius of his language. Instances do occur where an incongruous collection of elementary signs in the modern symbol resolves itself into a pictograph as the forms are traced back. Take the symbol "to fly" (*fei*) as an illustration of this, beginning with the modern form :  . Here, from a conventional modern sign, we trace the successive forms to that of an undoubted pictograph, wherein the idea of flight is beautifully portrayed.

The appended list of some four hundred symbols will suffice to show that etymology, when applied to the Chinese language, appeals mainly to the eye, and hence has more of orthography in it than it has of phonology, the main thing in the study of alphabetic languages.

Sources of Knowledge Concerning Early Chinese Writing.

The modern style of Chinese writing had its beginning in the reign of the founder of the Ch'in Dynasty (B. C. 240), when the substitution of the hair-pencil for the metal stylus (Fig. 1) for engraving hard surfaces wrought an important change in the shape of the symbols. Prior to that date the prevailing scheme was that of curved lines, due to the habit of engraving upon copper, stone, bamboo, or other hard substances by means of a metal point. This rendered curved lines easier of execution than straight lines and angles. The hair-pencil on paper did not lend itself readily to these shapes, and we find the "square character" in the ascendency until it entirely supplanted the older system of "seal character" about A. D. 400.

This change in penmanship so modified the appearance of the written signs as to greatly obscure and almost obliterate their pictorial character. Hence the neces-

[5] This resembles the pictograph for "kite," , see Plate XV., No. 204.

sity for seeking older sources of information than that afforded by the modern text. Fortunately we have many examples of the older text in (1) ancient inscriptions preserved in existing works by Chinese scholars, and in (2) exhumed inscribed objects of durable materials, such as bronze, copper, stone, and bone.

Fig. 1. Form of bronze stylus from specimens referred to Chou Dynasty (circa B. C. 500), reduced in size.

As to the value of the first source, there is a risk that intentional or accidental changes in the text may have occurred in copying from older manuscripts or from the original inscriptions. The Chinese have not the high reputation as faithful copyists[6] which is credited to the Hebrews, whose scribes were superstitiously careful in reproducing their Scriptures. Many errors have crept into the text of the Chinese classics, which are undoubtedly traceable to careless transcription.

The student must further be on his guard against spurious and forged inscriptions. Such was the reputed "Tablet of Yü," which first appeared as a manuscript copy purporting to have been taken from a stone tablet found on a mountain in the Yang-tze valley. Had it proved genuine we would have possessed an inscription of the greatest antiquity (circa 2200 B. C.). But this is now pronounced a forgery by the best Chinese scholars, both native and foreign.

Perhaps the best extant collection of ancient Chinese inscriptions is that published by a famous scholar of Yang Chow, Juan Yüan (阮 元), who in 1803 reëdited the work of an earlier scholar, Hsüe Shang-Kung (薛 尚 功), adding sixty-seven transcriptions to the four hundred and ninety-three of the original treatise.

The vocabulary obtained from all these is very limited, for most of the texts yield only the conventional phrases inscribed upon sacrificial vessels, halberds, and swords. One inscription of three hundred and fifty-seven symbols is referred to the reign of Wu Wang (武 王) (circa B. C. 1122), and affords the oldest known Chinese writing of determinate date. (See *infra.*)

Inscribed objects of undoubted genuineness, which have been exhumed, while they prove the most reliable source of knowledge of ancient writing, are far from satisfactory in that it is seldom possible to fix their dates. The ancient Chinese had a tantalizing habit of carefully inscribing the number of the year,[7] month, and

[6] In fairness to Chinese authors, their first editions are usually accurate. It is in reprints that numerous errors occur through careless proof-reading.

[7] Chinese chronology is not on a consecutive basis upon an established era, but upon the successive reigns, often substituting the cycle-year for year of the reign.

day, and omitting to designate the reign. Their ancient sacrificial tripods and libation cups are often inscribed thus: "Tenth year, first moon, I make this vessel as a precious memorial for the perpetual use of my descendants" (子孫永寶用). Had only the solicitous ancestor added the current reign, how much more valuable would have been his message to the antiquarian of to-day.

An extensive find of inscribed tortoise shells and bones of sacrificial animals was made by Chinese in 1899 while digging in or near the ancient city Chao Kuo Ch'êng (朝歌城), now Wei-Hui-Fu, in Honan Province. These have been reviewed by the writer and found to be inscribed in an archaic style difficult to decipher. The entire set of inscriptions may yield 600 different symbols, and are probably referable to the early Chou Dynasty (circa B. C. 1000). (See *infra*.)

Small bronze objects which furnish meager data to the investigator of early symbolism are coins, seals, and martial accoutrements, such as swords, spear-heads, buckles, chariot hubs, and crossbow triggers. These furnish a limited vocabulary of geographical names and numerals, together with devices and monograms the significance of which has been lost.

The inscriptions on coins are prolific in names of cities, numerals, and mint-marks of uncertain meaning. Contracted symbols are frequently noted on ancient Chinese coins, just as on those of other nations, and allowance must be made for this when comparing these symbols with the fuller forms found elsewhere. Thus 𠂤 appears for 𠂤 (modern form 當) used to this day to specify the denomination of a coin. 𠂤 often appears for 貝 (modern form 貨), "exchange" or "commercial value."

Bronze and stone seals by their nature and use contribute but little to the list of ancient symbols, monograms and fanciful signs having been in use for this purpose from the earliest times.

Trade-marks on pottery afford a few old symbols, especially those found on fragments exhumed on the site of ancient cities the date of the overthrow of which is approximately fixed by history or tradition.

Another important source of information is the Etymological Dictionary of the Han Dynasty, known as the Shuo Wên (說文) "speech signs," which was compiled by the scholar Hsü Shen and first published A. D. 120. The opinions of Sinologues have differed widely as to the value of this work. After making allowance for a corrupt modern text, and for the frequent flights of imagination made by the author, it must be conceded that this celebrated work ranks high as an etymological treatise, when compared with like works upon European languages produced at a much later date by Western scholars. As an incidental evidence of the conscientious

thoroughness of this Chinese lexicographer, he remarks concerning the symbol 也 *yĕ* that on the standard measures of Er-shih Huang-ti 二世皇帝 (B. C. 230) the form 𠂤 appears. For centuries nothing else was known of this unusual form until a set of these old "standard measures" was unearthed, and there appeared the sign 𠂤 exactly as the lexicographer had noted.

Unfortunately the original text of this famous dictionary is not extant, for all modern editions show the old symbols analyzed by the author Hsü in the style called "small seal"—a refined form developed during the Han Dynasty (B. C. 206–A. D. 264).[8] Another valuable work on the ancient language is the Liu Shu T'ung (六書通) "Comparison of the Six Scripts."

Still another valuable treatise is that by a scholar of Shantung Province, Chou 周 by name, whose beautiful and accurate syllabary of the ancient Chinese language is based upon the Liu Shu T'ung. It appeared in the ninth year of the Emperor Kang-hsi (A. D. 1670), and is printed in black and red ink for perspicuity.[9] The author adds a vast number of old symbols copied from antique bronzes and stone tablets, presumably in private collections of Chinese antiquarians.

These works show evidence of careful transcription and classification of symbols, but with characteristic vagueness, the authors fail to record exactly how and where they obtained their information and data. Nevertheless I consider these catalogues fairly reliable, barring typographical errors so frequent in Chinese books.

CHINESE IDEOGRAMS.

Origin of Chinese Writing.

The beginning of the Chinese written language is lost in obscurity. The popular tradition that it began with knotted cords[10] and developed through the grotesque "tadpole letters," has little to substantiate it. It is true that many ancient inscriptions are extant, the symbols in which are formed by alternating light and heavy strokes resembling the form of tadpoles, but when these are reduced to plain writing they will be found to belong to a highly developed orthography not differ-

[8] As proof that the original text of the Shuo Wên was in a more archaic style, I notice that the forms quoted by a Chinese etymologist of A. D. 1670, differ from those now extant. This writer must have had access to a text of the Shuo Wên nearer to the original than that of to-day.

[9] A complete copy of the first edition is in possession of the writer.

[10] Granted that the Chinese, like other peoples in their primitive state, used knotted cords, it does not follow that such a system of recording and transmitting ideas had intimate connection with a scheme of pictographs subsequently devised. It is even possible that at an early date the tradition of a knotted-cord system was so current as to lead writers to imitate it in inscribing their written signs, just as they delighted to make ornamental inscriptions, weaving birds, beasts, and insects into all the characters.

ing essentially from the well-known "seal character" of the early Han Dynasty (B. C. 200).

A more reasonable conclusion is drawn from what we find in the most ancient inscriptions, to wit, that the Chinese, like most other peoples, began to record ideas by scratching rude pictures upon wood, stone, bone, or metal, in order to suggest the thought to be conveyed. Among these rude beginnings of language are found the outline drawings of animals, wild and domestic, which soon assumed conventional forms merely suggestive of the more elaborately carved originals. In one instance a tiger is represented with the attached symbol for "tree" as if to indicate that the beast inhabited the jungle, the sign (米) being identical with 木 "tree."

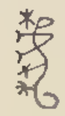


FIG. 2. Ancient symbol for jungle tiger.

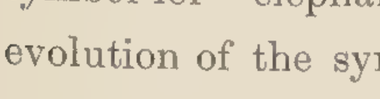
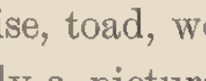
The oldest preserved inscriptions are found upon bronze vessels and implements, upon stone and brick tablets, on bones used in sacrifice and divination, and on bronze coins vaguely referred to the Yin, Shang, and early Chou Dynasties (B. C. 1100–2000), as already noted.

Such inscriptions are unsatisfactory because of their brevity, and, in the case of coins, on account of the habit of abbreviation in order to save space and labor. This last unfortunate characteristic renders the coin-inscriptions at once difficult to decipher, and unreliable as complete specimens of early symbolism. It seems a safe inference from the oldest inscriptions on bronze vessels and tablets that the original Chinese writing was pictographic.

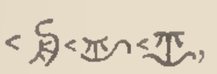
Pictographs, as found among these primitive symbols, may be divided into two kinds, (1) those based upon the form of the object as (now 丁)[11] picturing the head or side-view of a "nail," or as and the right and left hands (contracted from and which show the five fingers), and (2) those suggested by some real or imaginary characteristic of the object, as (now 父) "father," composed of a vertical line attached to ("right hand") and signifying a "rod in the hand" as a sign of authority, hence "father," who was the absolute ruler of the household or clan. Wang Chun of Shantung, one of the greatest of modern Chinese scholars, whose commentary is embodied in recent editions of the Shuo Wên, states in his preface that writing began with pictures of things which appealed to the senses. These developed into abstract ideas, and these in turn gave rise to indefinable particles such as conjunctions and prepositions (classed by the Chinese under the general term of "empty symbols"). The same scholar gives numerous examples of this

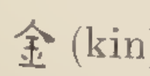
[11] Chinese, following the Shuo Wên, consider this as originally the picture of an insect's sting. This will not account for the form , and the author of the Shuo Wên adds that when men made nails of metal and wood, these were allied in form to a sting (). I prefer to consider the nail as the original basis of the sign.

development, and while he introduces some absurdities, yet in the main makes a plausible argument for his theory of the origin of the written language.

Many of these primitive pictographs are still in use, but so altered, owing to the present changed style of penmanship, that they are not recognizable until they are compared with the successive preceding forms. Take, for example, the modern symbol for "elephant" (象). How little it resembles that animal! But note the evolution of the symbol through extant earlier forms:  . To anyone accustomed to study orthographic changes, the proof is positive that 象 is only the original pictographic "elephant," with position altered for convenience in writing vertical lines. The same evolution may be discerned in the symbols for most of the animals known to the Chinese, as dog, sheep, cow, horse, deer, tiger, fish, snake, tortoise, toad, worm, bird, and swallow. The sign for "man" (Latin *homo*), 人, is plainly a picture, derived thus,  , the legs being apparently the only surviving members.

Plant life was also pictorially portrayed. 木 "wood" was originally 𣏌 "tree," showing branches and roots. 林[12] is two trees and signifies "forest" or "grove." 艹 "herbs" was once , depicting leaves and twigs. 表 "indicator" can be traced back to a "line-tree" or "hedge," marking the boundary of a field, being a clump of bushes pictorially suggested.

Inanimate objects came in for a full share of pictorial representation. 舟 "ship," in its modern form, is scarcely recognized as an ideogram, but trace it back thus,  , and we begin to detect its likeness to a Chinese junk, though whether a side view, or that of a ship's compartments (), may be an unsettled point.

金 (kin) "metal" still approximates its oldest forms, as,  which probably refer to the process of smelting, being composed of two symbols for "fire" (火) or "intense heat" under a cover," (or), very suggestive of molten metal in the crucible.

Abstract ideas were also presented pictorially with considerable ingenuity. "East" being the "sun" (⊙) rising behind a "tree" () thus, (now written 東); "West" was suggested by a "bird on its nest" (), the transition of which into the modern form was as follows[13]: . Birds seek their nests at sunset, hence the idea "West." "Determination" was formed from "issue" (lit. "sprout" 士), and "heart" (), hence "heart-sprout," "heart-issue," *i. e.*, "purpose," "determination."

[12] Still older forms of this show interlaced branches of trees.

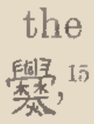
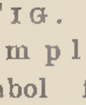
[13] Another old form is .

"To look" was light streaming from the eye, thus, (now written 見) based upon a peculiar notion still held by the Chinese that when blind "no light comes out of the eyes" (眼 不 出 光). "Large" was a man on another's shoulders — a man above another — (, the last being the modern form). The popular idea that 大 ("large") is a "man" (人) above the "average height" (shown by the horizontal line) is hardly sustained by the oldest forms.

Elaborately wrought pictograms were attempted at a very early date, of which two examples will suffice as illustrations:

"pao" (now, 寶) denotes "valuable," "precious," ideas suggested by a "house" (宀) containing "jade beads" (or 玉), "shell" ( ) and an "earthern jar" (缶), articles of value to primitive man.[14]

FIG. 3. Complex symbol for cooking-stove.

"To cook" was perhaps the most complicated of all the ancient symbols. It is now written  ,[15] which retains all the elements of the original idiogram. It is now pronounced *ts'uan* and signifies "stove," and is obsolete, a simpler symbol having taken its place. The analysis is as follows:  from and 缶 "millet-bowl" and "jar"; 冂 "oven-mouth"; "wood-wood," *i. e.*, fuel; "two hands"; 火 "fire,"—all the essentials of cooking.

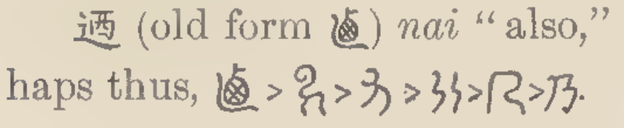
EVOLUTION OF THE MODERN SYMBOLS.

From comparison of the earlier and later forms of Chinese ideograms we ascertain four ways in which the modern style was evolved.

1. Contraction of early complex forms.
2. Expansion of early simple forms.
3. Artificial alteration, to conform to the inflexible system of radicals and phonetics.
4. Mechanical invention of new symbols, along conventional lines, by combining existing forms.

1. *Contraction of Early Complex Forms.*

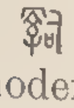
This process is common to all languages, whether ideographic or alphabetic. It grows out of the impatience of writers with unnecessarily complicated signs.

迺 (old form) *nai* "also," "but," has dwindled to 乃. The change was perhaps thus,  .

[14] This symbol appears with many variations in old inscriptions, sometimes ornately distorted, as , , .

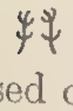
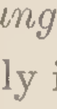
[15] Complex as this symbol is, it is placed among the five hundred and forty primitives in the Shuo Wên and must be of great antiquity.

 ching, "a well," soon became , discarding the well mouth and retaining only the curb. It now appears as . The ancient division of land into nine plots, thus, , had for its symbol . This, from its resemblance to the symbol for "well," gave rise to the expression "well-field" in common parlance. Doubtless this had some influence in simplifying the sign for "well."

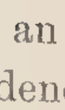
 *sï*, "retainer," became (modern) by rejecting the significant sign (modern) "bind." It passed through the meaning of "petty-officer" to that of the verbal sense "manage."

hsin "heart," originally a picture of that organ, is now merely .

kung "together," originally two pairs of hands united, became .

 *kung* "fear" was at first "hands raised as in terror," but is now reduced to  (used only in combination). Many of the earliest extant forms had already been contracted from more elaborate ideograms, now lost, thus rendering their original significance difficult to determine.

2. *Expansion of Early Simple Forms.*

At an early stage in the development of the language, confusion arose out of the coincidence in form of symbols having widely different meanings. Thus *shih* "ten" gradually became  , and coincided with an existing symbol which meant "at" or "here." The latter was accordingly expanded to *tsai* by the addition of a sign of disputed significance. A like confusion arose between "ten" and an early contraction of *kia* (now) "finger-nail." The latter resumed its more complex form.

tso "left-hand"[16] and *yu* "right-hand"[16] seem to have been satisfactory signs till after B. C. 1000, when they became respectively ( ) and (). Why the sign ("labor") should have been added to strengthen the idea of "left" is hard to say, unless the left-hand was once used to such an extent as to make it the important member for work. "mouth" was added to emphasize "right-hand," possibly because that member was used in eating. Whatever may have been the significance of these additions, the fact remains that the older symbols were thus amended.

Another strange instance was that of or *tso*, "make," to which "man" was added, thus, (modern) as if to indicate that man is the prime *inventor*.[17]

[16] Some writers in describing these signs have reversed them. The right hand naturally points toward the *left* and *vice versa*. This is plainly shown in the old forms for and , viz., and .

[17] The sign is of very obscure origin. It resembles an inverted ax () with stroke added. Possibly an ax or adz in position of chopping. This is a mere conjecture.

3. *Artificial Alteration of Old Symbols.*

The earliest recorded attempt to artificially reduce the heterogeneous written signs to a system was by one Chou (籀), of the eighth century, B. C., who became a literary authority in the state of Chou (周). His very flowery system of writing has since borne his name, being referred to in all Chinese works upon the history of the language as "Chou Wên" (Chou-writing).[18]

Following this, but of disputed date, was the catalogue of signs called *Er Ya* (爾雅). The next great effort to classify the existing symbols was by the author of the Shuo Wên, Hsü (許), whose posthumous lexicon appeared A. D. 120, as already stated. He classified all existing characters under 540 primitives, which gave rise to the modern classification under 214 primitives ("radicals"). This conventionalization of the written language forced many incongruous symbols into classes with which they had no etymological affinity. These isolated ideograms were artificially changed that they might be classified for ease of lexicography. A marked instance of this was the symbol 𣏌 *piao*, to which reference has been made above. This was originally the picture of a mulberry bush or other shrub used to mark the boundary of a field. It depicts a bunch of sprouts. Later it took the general meaning of "indicator" and to-day it is applied to any instrument which records or marks degrees, as a watch, barometer, cyclometer, etc. This interesting sign now appears under the "radical" or primitive 衣 "cloak" in the anomolous form 表, seemingly composed of a modified 主 "lord" and 衣 "cloak," neither of which signs have anything to do with its original form or meaning.

萬 *wan* ("myriad") is another case in point. It now is classified as if derived from 艸 "plants," but this is an artificial modification, for the oldest forms are 𢀛 and 𢀛, picturing some prolific creature as the scorpion or frog.[19] The antennæ of the scorpion or fore-legs of the frog have been confounded with 艸 (艸) "plants."

The modern character 魚, *yü*, "fish," happens to be itself a "radical," but has been so altered as to appear to contain the symbol 灬 (modified form of 火), "fire." This is misleading, for the "fire" is only the fish's tail; thus 𩵦 > 𩵦 > 𩵦 > 𩵦 > 𩵦 > 魚.

The symbol for "swallow" (a bird) 燕 is analogous to that for "fish," but now is classified under the radical 火 "fire," contrary to its origin, the development of the pictograph having taken place as follows: 𤇾 𤇾 𤇾 燕.

The above examples plainly show that the radical and phonetic system was an invention at a date long after the heterogeneously devised symbols had become current in writing, and even the compounding of signs had come into vogue.

[18] This highly ornate style of writing was not generally adopted on account of the complexity of the symbols.

[19] Analogous to the Egyptian use of the sign "frog" for 100,000.

4. Mechanical Invention of New Symbols.

This class of new characters forms by far the largest, comprising perhaps nine-tenths of the forty-five thousand symbols known to Chinese lexicographers. Ten thousand signs is an ample number to put to the credit of the Chinese language at the beginning of the Christian Era. This roughly marks the date when the mechanical multiplication of characters became excessive. The process was simple, that of combining existing forms according to the conventional system of radicals and phonetics. Indeed, for purposes of etymology three thousand symbols are all that need be examined, the artificial combination of signs having been begun as early as 500 B. C.

In every branch of industry new usages were requiring new names. This lack was supplied by the simple, though often clumsy, union of two or more existing signs, usually annexing a "radical" to suggest the nature or material of the new thing. Most of these new characters were short-lived, and to-day the basis of the written language, as used by scholars, is still the few thousand symbols of the classical period (B. C. 500–200).

Erroneous Deductions from the Modern Style of Chinese Writing.

Mistakes in comparative orthography frequently occur by drawing conclusions from the modern Chinese "square-character," which has so far departed from the original pictographic style as to be an unsafe guide to the casual observer. Occasionally symbols are found, which to-day approximate their originals more closely than do the intermediate "seal characters."

A few examples may be cited of such pictographs as have passed from a primitive angular style through the rounded form of the "seal character" into the modern "square-character," in which form they coincide with the original shape. Take the modern symbol 田 *t'ien*, "field." Formerly it was ⊕, but originally it was 田, a subdivided square farm. 口 *wei*, "enclosed area," was originally, as now, a square, but was long written thus ○, when curved lines prevailed. But in general it is unsafe to use the modern style of writing for philologic deductions.

The following will serve as examples of the misleading nature of modern forms:

The symbol 木 *mu*, "tree," might suggest a rooted tree projecting above the ground, and, indeed, has been frequently so interpreted, but the original form, 𠦂 or 𠦂, shows a tree with branches and roots.

朋 *p'êng*, "friend," looks as if it were twin moons (月) or, as has been actually inferred, the duplicated sign for "flesh."[20] But in fact this symbol is a contraction of a more complex form 𦥑, "a pair of birds," a happy symbol of "friendship."

[20] 肉, "flesh," in combination usually appears as 月. Some have supposed 朋 to have been 𧊒, "a pair of shells," but I find no authority for such a derivation.

A certain writer has assumed the sign ⿱ to be the original of ⿱, "sun," and on this erroneous hypothesis he makes the imaginary sign ⿱ to correspond to "the trident of the three seasons of Orion." Had he noticed that ⿱ was once ⊙, such a conclusion would have been impossible.

⿰ *pi*, "ought," a sign of duty or necessity, looks like "heart" (⿱) cut by a stroke. Imagination might work out a theory based upon the heart cut or pricked by a sense of duty. No such psychological process is even hinted at by the early forms of this character, which are ⿱ ⿱ ⿱ ⿱ ⿱ ⿱ ⿱. The last of these enigmatic forms (⿱) is the "small seal" character of the Han Dynasty, which is the nearest chronologically to the modern "square character" ⿰. The two vertical curved lines of the older form correspond to the right and left dots of the present form, while the part ⿱ has now become ⿱, the central portion of the modern symbol. The resemblance to "heart" is thus merely accidental. None of the old forms have any suggestion of ⿱, which is the old writing of ⿱, "heart."[21]

Incongruity Between Form of Symbol and Meaning.

Let us now glance at another phenomenon of orthographic evolution, the enigmatic form and sense of many Chinese symbols.

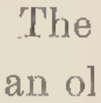
Certain modern forms have such a variety of unrelated and conflicting meanings as to raise the suspicion that they present under one form a common resultant from several different roots. Thus ⿱ *t'ai*, "lofty, large," is defined in the Shuo Wên as "slippery." A comparison of the old forms shows a divergence, as we go back, toward two separate roots, *viz.*, ⿱, which is three times the sign ⿱, "large," forming an intensive signifying "very great," and ⿱, composed of "clay" ⿱, "hands" ⿱, and "water" ⿱, a very appropriate symbol for "slippery." The modern symbol contains elements of both of these roots, though it retains only the meanings derived from its root ⿱. It is safe to conclude that ⿱ *t'ai* is a composite of both of the old symbols described.

The sign ⿱ *jüe* means "harmonious," and also "a certain mythical tree." These apparently incongruous definitions can be reconciled when we find among the old forms ⿱, three hands together, *i. e.*, "harmony." Again, we encounter ⿱, which is a symbol of vegetation and suggests the "tree," of which ⿱ *jüe* is the name. These both coalesced in ⿱ and so give us the one symbol from the two widely different roots.

⿱ *tang*, means "ought," "count," "considered," "to pawn," to "obstruct,"

[21] There is a striking analogy in some of the old forms of ⿰ with those of ⿱ *chao* "omen," *viz.*, ⿱ ⿱ ⿱ ⿱, supposed to be lines on tortoise shell used for divination.

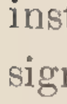
etc., etc. The phenomena exhibited in its old forms lead us to suspect that it, too, is an incongruous composite from more than one root.

The character 治 (*Chih*) is the name of a river, and also means "to govern," "to control." The oldest forms show confusion of origin.  plainly designates a river, being an old form for "stream," but , , , also occur as synonyms, and are analogous to (now 司 "to govern"). A possible conclusion is that these varied forms have coalesced in , which retains the several meanings of its components.

Just as in other languages, the early juggling with orthographic signs has led to puzzles in the shape of monographic signs which are the despair of the philologist, unless he can recover the lost key.

A curious phase of this juggling with writing-signs appeared at an early date in the development of the Chinese language. I refer to the habit of reversing or inverting an existing sign to signify its opposite in meaning. This forms a distinct class of mechanically devised symbols.

The process may be illustrated thus: Having accepted an English word "hard" as descriptive of unyielding substances, we might have adopted "drah" (the reversed spelling of "hard") as suitable for the opposite meaning "soft." Or, being familiar with the meaning of "child," we might have reserved it to signify a child of good conduct, and then have written "pɪɪɥɔ" (letters inverted) to mean a "prodigal son" who has turned normal conditions upside down. Such a conception actually seized the ancients in China when they represented "unfilial" by 𠫓 (now written 𠫔 *t'u*), the inverted character 𠂤 for "son" (now written 子 *tzï*). Another instance is that of the now obsolete sign 𠂤 *i* which was formerly written 𠂤 and signified "to turn back." It is the reversed symbol 𠂤 (身 *shen*) for "body," and hence was considered appropriate for the idea of "about face."

 (now twisted into 乏) means "deficient," and in form it is the reverse of 正 *chêng* "exact," the latter being the older symbol. Again, having become familiar with the sign (now altered to 絕[22] *chüe*) as meaning "sever," depicting "cut silk" (), it was little short of an inspiration that led some scholar to adopt the reverse for the idea of "connect," a symbol now enlarged to 繼 "*ki*."

The effort to construct ideographs for the negatives "no," "not," "not yet," "without" and "do not," seems to have taxed the ingenuity of the ancient sign-

[22] We have in this form a survival of an old variant written composed of "silk," "knife" and "knot" equally suggestive of "cutting." It is further curious to note, among the old forms of *ki*, "to connect," several which seem to be with variations. This may be *fei*, "not," and , "sever," which would be another way of reversing the meaning of the sign.

makers of China, as will be seen by noting the special list of negatives (see Plate XXVIII.).

The most complicated of all these is the sign 無 "*Wu*," "minus," "without." In its modern garb it suggests a likeness to 血 *hsüe*, "blood," and 火 *huo*, "fire." In fact, it is connected with neither of these, though for convenience it is classed under the latter. Taking the old form 𣏌 as a means of comparison, we find the upper part (𠂤) has been condensed into 𠙵, leaving the "two trees" (𣏌) as the origin of the base of the modern symbol 灬. The Shuo Wên defines it as "lost" probably from the sign 亡 in many old forms, which has that meaning. The inference by the commentators of the Shuo Wên is, "'man' (人) 'lost' (亡) in the 'woods' (𣏌) hence 'missing' 'minus.'" This is a far-fetched explanation and fails to account for an essential part of the old symbol 𣏌[23].

The list of pictographs and ideograms represented in Plates I.–XXIX. is neither complete nor strictly logical in arrangement. They have been selected somewhat at random to illustrate the pictorial nature of the language. Many of the symbols given will not be found in the current Chinese-English dictionaries, for the obvious reason that these works are abridged, excluding many obsolete signs which, however, played an important part in the early development of the written language. I have tried to give the original meanings (where ascertained), which often seem remote from their modern significance. No attempt has been made to indicate the old pronunciation, which forms a different branch of philology from that herein discussed. I have followed, in the main, the Wade system of Romanization, with a few changes which seem expedient in view of the poverty of sounds in the Peking Dialect, upon which Sir Thomas Wade based his system.[24] I have departed from this system in distinguishing between the two initial sounds "ch" and "k," which coalesce in Pekingese, and have introduced a few minor changes noted in the key.

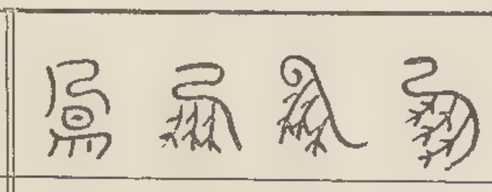
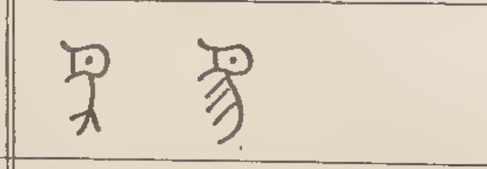
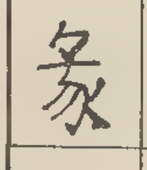
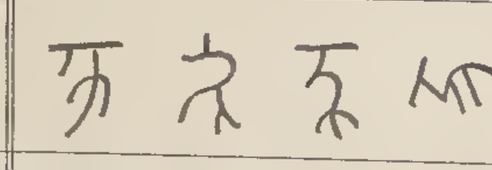
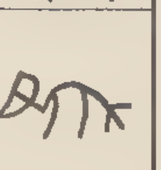
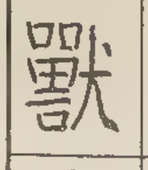
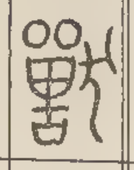
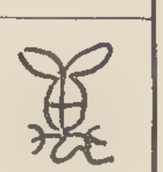
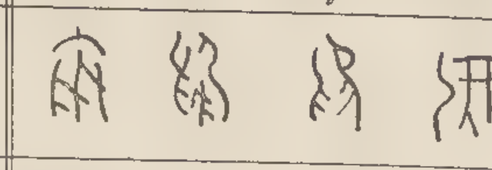
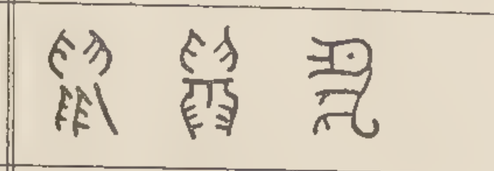
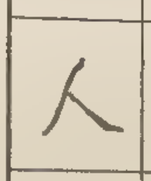
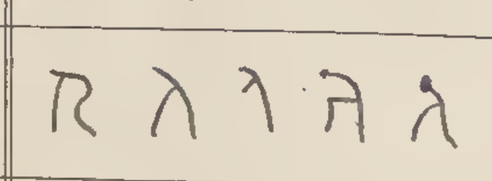
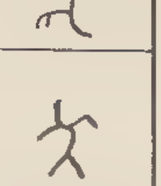
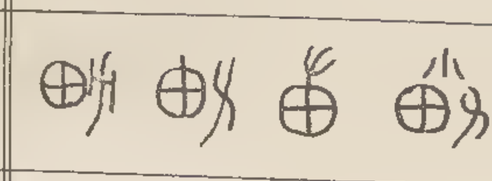
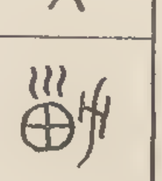
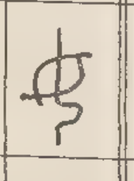
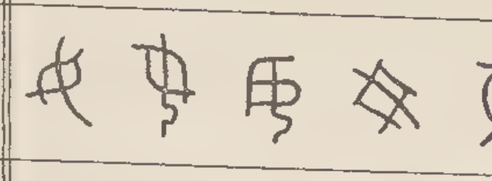
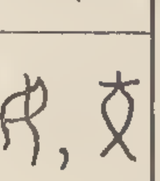
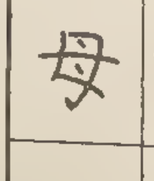
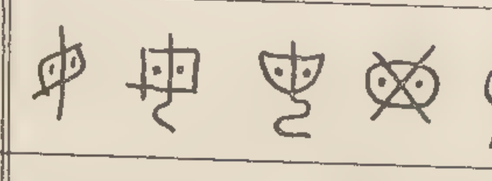
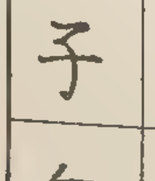
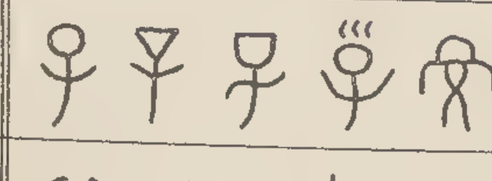
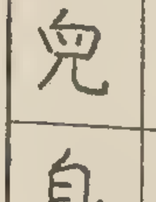
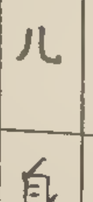
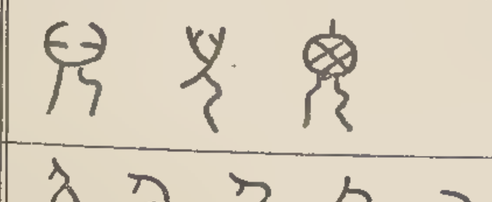
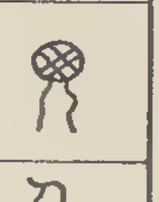
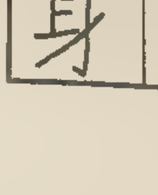
Of the many systems of Romanization in vogue, that by Sir Thos. Wade is the most widely known. It is the standard of pronunciation used by the British Consular Body, by the Chinese Customs and Postal Service, and by Dr. Herbert Giles in his Anglo-Chinese Dictionary. It is also used largely by contributors to the Journals of the Royal Asiatic Society. This has naturally given wide circulation to Wade's system, and is sufficient reason for its adoption in this paper. The changes introduced have been due partly to the author's choice, and partly to suggestions made by others.

[23] See note at Plate XXVIII.

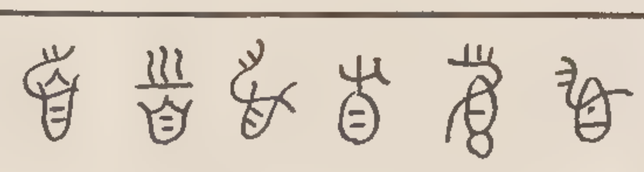
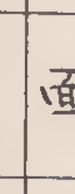
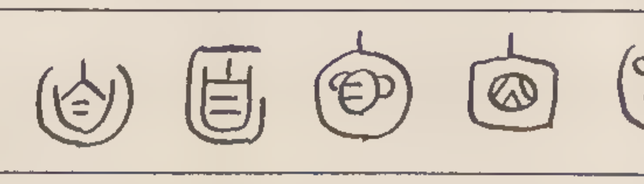
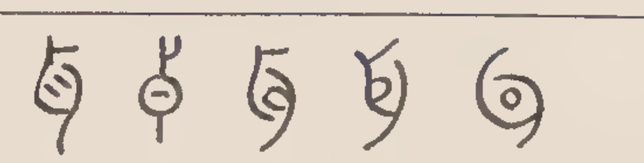
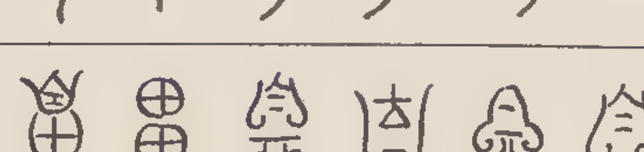
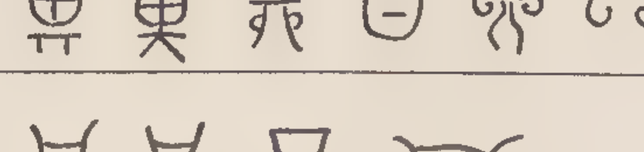
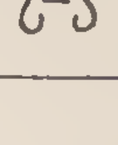
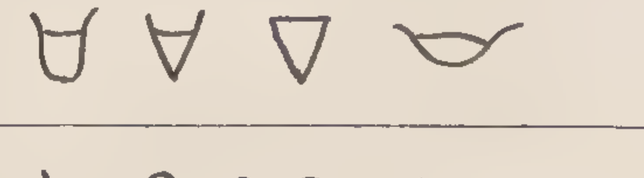
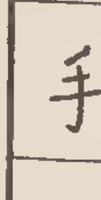
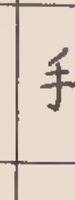
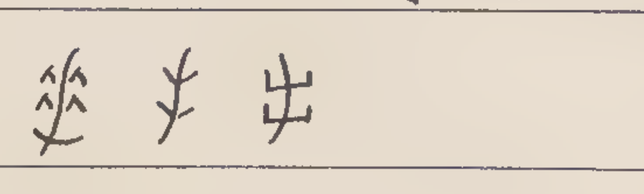
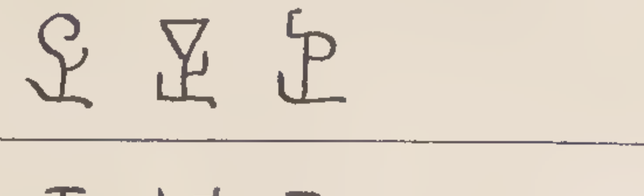
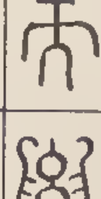
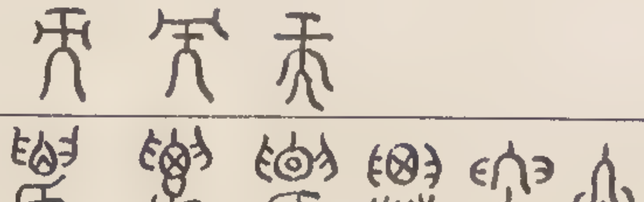
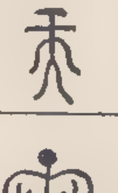
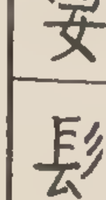
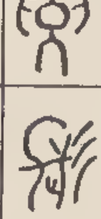
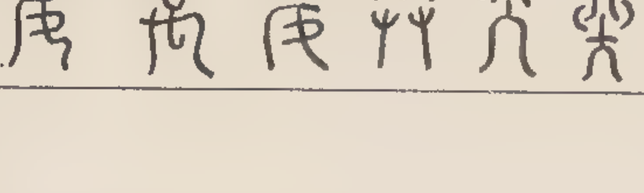
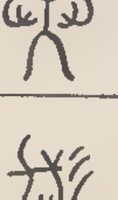
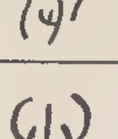
[24] A comparison of the dialectic variations in sounds — especially the old sounds — will show the inadequacy of Wade's System to indicate them.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
1	Elephant, Image, *hsiang.*	象	豕	象			Shuo Wên: "Large beast in Kiangnan, with long proboscis and tusks. A picture." Ivory carving suggests 'image.'
2	Tiger, *hu.*	虎	虎	虎			Rude outline of a tiger.
3	Stag, *lu.*	鹿	鹿	鹿			
4	Horse, *ma.*	馬	馬	馬			
5	Ox, cow, *niu.*	牛	牛	牛			Suggests a horned animal.
6	Ram, sheep, *yang.*	羊	羊	羊			Outline of ram, with horns prominent.
7	Dog, cur, *kou.*	犭, 犬	犬	犬			Animal with curled tail (like Chinese cur of to-day).
8	Fish, *yü.*	魚	魚	魚			
9	Toad, *min.*	黽	黽	黽			Original form is deduced from the extant forms.
10	Tortoise, *kuei.*	龜	龜	龜			Original form is deduced from the extant forms.
11	Worm, insect, *ch'ung.*	虫	虫	虫			Worm with convolutions.
12	Long-tailed bird, *niao.*	鳥	鳥	鳥			
13	Short-tailed bird, *chui.*	隹	隹	隹			
14	Swallow, *yen.*	燕	火	燕			Flying bird with forked tail.

CHINESE IDEOGRAPHS.

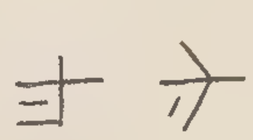
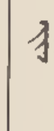
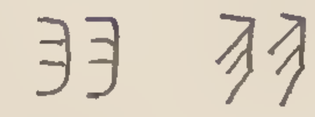
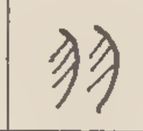
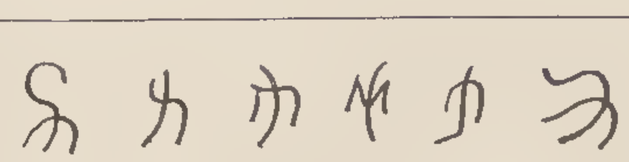
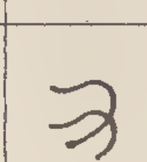
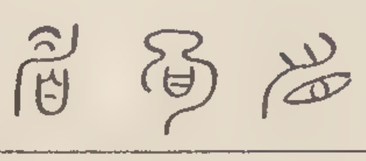
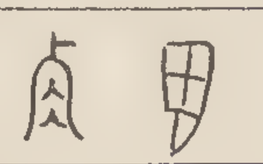
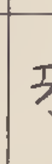
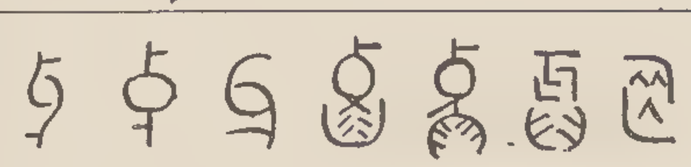
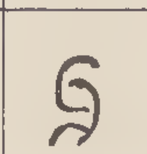
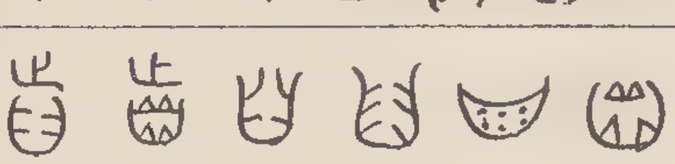
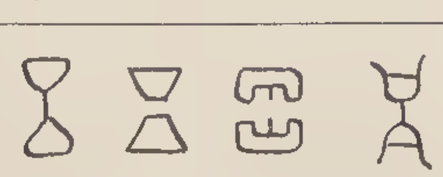
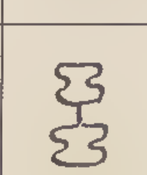
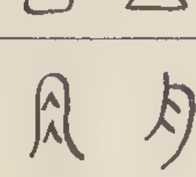
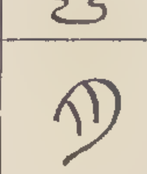
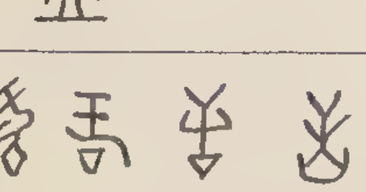
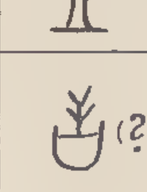
	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100	Older Forms.	Probable Original.	Remarks.
15	Phœnix, *fêng.*						Originally a picture of the phœnix, but now a bird's head and *bird* radical.
16	Unicorn, *chi.*						Original is deduced from extant forms.
17	Rhinoceros, *hsi.*						
18	Pig, *tuan.*						Rude picture of a pig.
19	Wild beast, *shou.*						Sign suggesting a beast, with *animal* radical added later.
20	Raven, *wu.*						Derived from No. 12, the raven being perhaps the most common of long-tailed birds.
21	Mouse, *shu.*						Rude picture of a rodent. Shuo Wên: "General name for burrowing vermin."
22	Man (generic), *jên, yin.*						Equivalent to the Latin "*homo.*"
23	Man (male), *nan.*						"Weedy-field" and No. 48, "muscle," suggesting man's labor.
24	Woman, *nü.*						Human figure with bust prominent.
25	Mother, dam, *mu.*						Woman with paps prominent. (Used also of animals.)
26	Son, child, *tzŭ.*						Male infant.
27	Son, *êr.*						Shuo Wên: "Form of child's head." (Synonym of last.)
28	Human body, *shên.*						Outline of the body with "man" above it.

CHINESE IDEOGRAPHS.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
29	Head, *shou.*						Outline of face with hair above.
30	Face, *mien.*						Original is deduced from extant forms.
31	Eye, *mu.*						Oblique eye (peculiar to the Chinese race).
32	Ear, *êr.*						Outline of the human ear.
33	Nose, *pi.*						Picture of the nose, with phonetic 畀 "pi" added later.
34	Mouth, *k'ou.*						Shuo Wên: "That with which man eats and speaks. A picture."
35	Hair, *mao.*						Possibly depicts a hairy tail.
36	Hand, *shou.*						Five fingers.
37	Foot, *tsu.*					(?)	Contains No. 110 "stop." Descriptive sign, not pictorial.
38	Whiskers, *êr.*						Shuo Wên: "Cheek-hair." Rude picture of whiskers. Now used only as a disjunctive particle.
39	Waist,* wish, *yao.*						(See note.)
40	Hair of the head, *piao.*						Descriptive symbol composed of two signs "long" and "feathers."
41	Heart, *hsin.*						"Heart" showing ventricles.
42	Finger-nail, *kia.*						Usually used as cycle-sign, being first of the "Ten Stems."

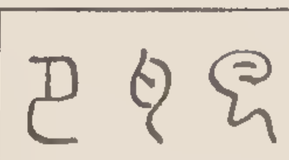
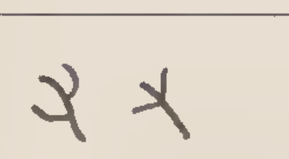
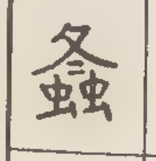
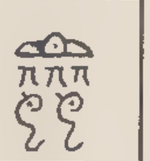
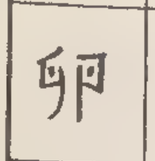
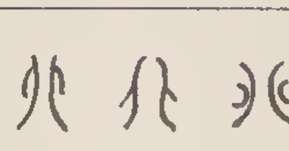
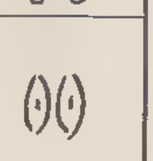
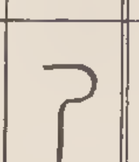
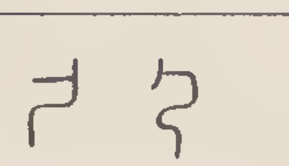
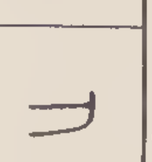
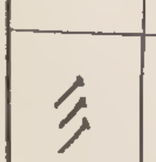
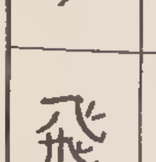
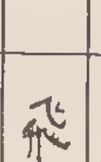
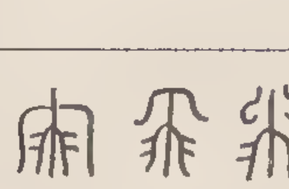
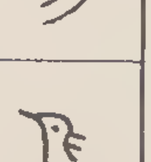
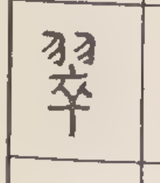
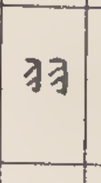
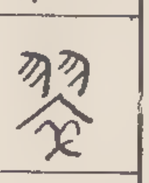
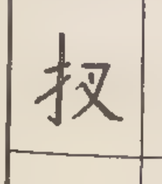
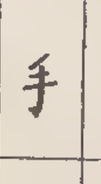
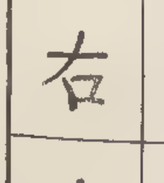
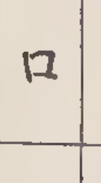
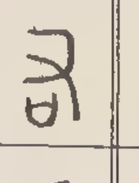
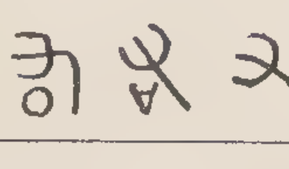
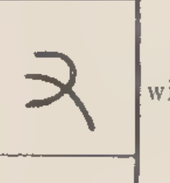
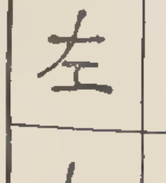
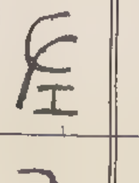
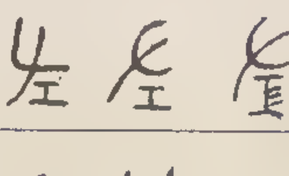
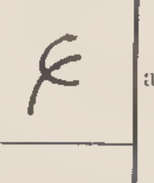
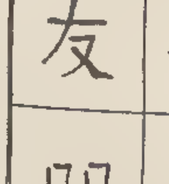
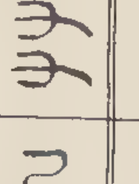
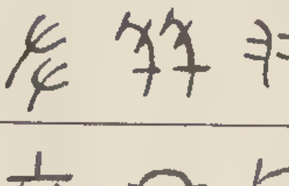
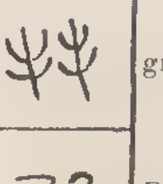
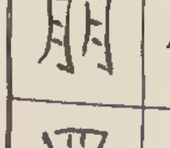
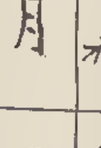
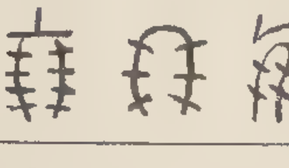
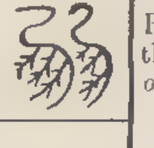
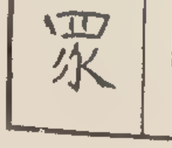
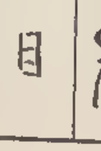
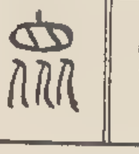
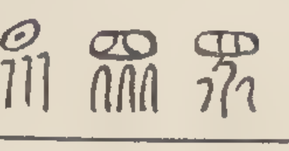
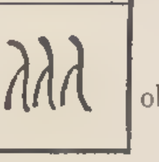
CHINESE IDEOGRAPHS.

* The original here given is an actual form. Figure with arms akimbo, hence "waist." This sign was early adopted for "yao," meaning "wish," and so the *flesh* radical was added to strengthen its old meaning "waist," thus 腰.

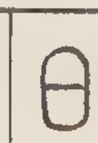
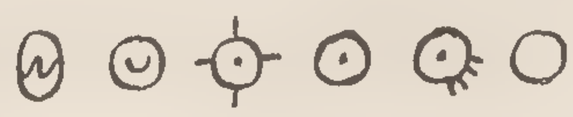
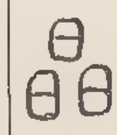
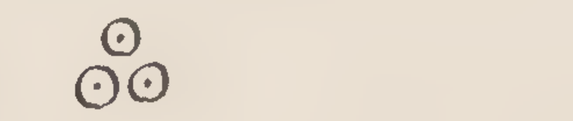
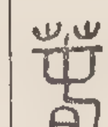
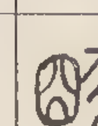
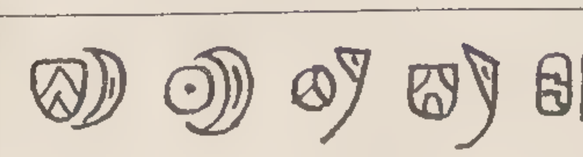
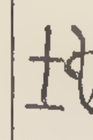
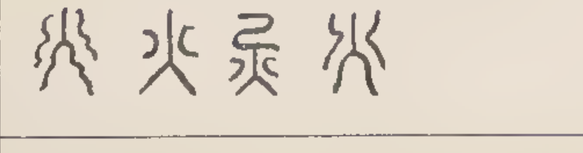
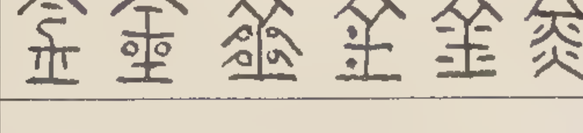
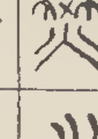
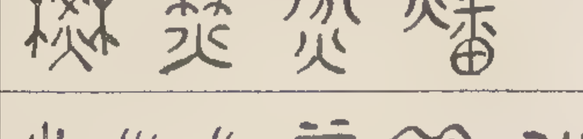
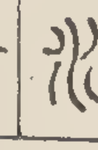
	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
43	Finger joint, inch, *ts'un.*						Fingers with short stroke suggesting "joint."
44	Claw, talons, *chao.*						Shuo Wên: "Nails of finger and toe."
45	Wings, *yi.*						Pair of wings, or long feathers.
46	* Form, appearance, *mao.*						
47	To gape, *k'an.*						Open mouth. *Cf.* No. 34.
48	Sinew, strength, *li.*						Overlapping muscles.
49	Eyebrows, *mei.*						Eye with eye-brows.
50	Horn, angle, *küe, kiao.*						Earliest forms are inverted.
51	Tooth, molar, *ya.*						Probably shows the grinding surface of a molar.
52	Front teeth, *ch'i.*						Mouth showing teeth. Phonetic was added later.
53	Backbone, *lü.*						Vertebræ.
54	Flesh, *jou.*						Sign suggesting a mass of flesh.
55	Blood, *hsüe.*						Shuo Wên: "Sacrificial blood in a dish."
56	Tongue, *shê.*						Tongue protruding. Older forms than these might suggest the original.

CHINESE IDEOGRAPHS.

* Depicts the human form, especially the face (contracted to the sign for "nose"), which now coincides with 匕 "pai" by further contraction. Its special significance is "individuality," "decorum."

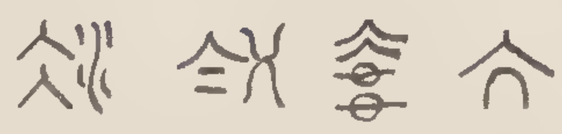
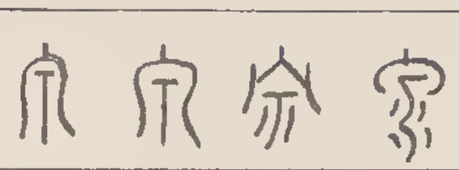
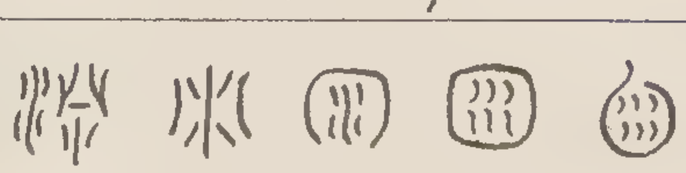
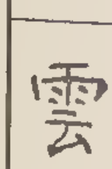
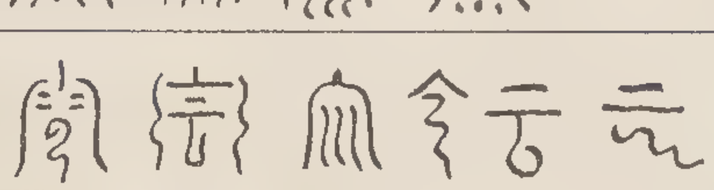
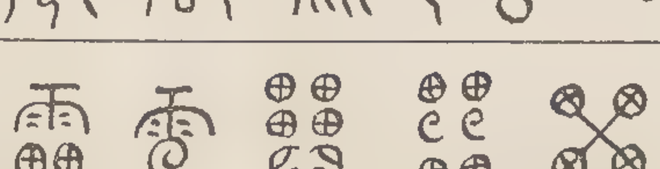
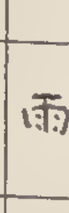
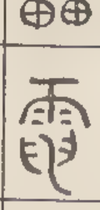
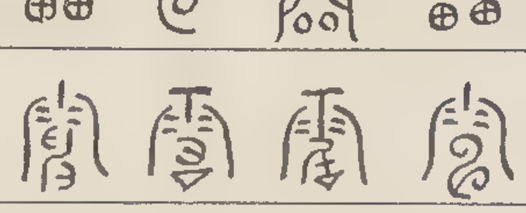
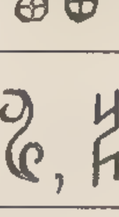
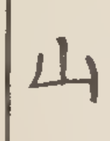
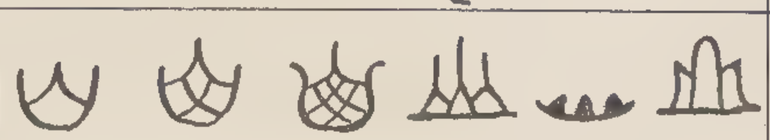
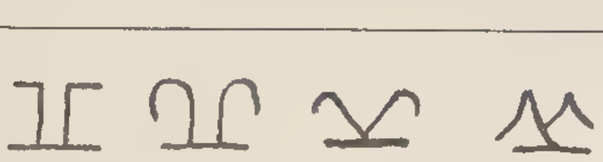
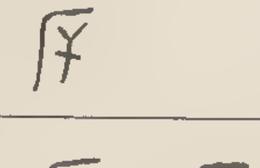
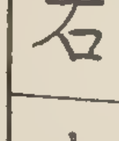
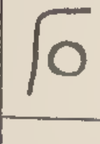
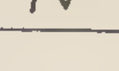
	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
57	Worm, winding, *pa.*						Closely allied to No. 11.
58	Right hand, also, *yu.*						*Cf.* No. 66.
59	Grasshopper, *chung.*						"Multitude" (now contracted) and "insects."
60	Eggs, *luan.*						Shuo Wên: "Eggs of all oviparous creatures." Also means "testicles."
61	Corpse, *shih.*						Sign for man recumbent. (Now 44th radical of an incongruous group.)
62	Feathers, stripes, *shan.*						Sign suggesting feathers. Used only in combination. *Cf.* No. 40.
63	To fly, *fei.*						Bird flying.
64	Kingfisher, *ts'ui.*						Descriptive sign from "feathers" and "cloak" referring to plumage.
65	Folded hands, *ch'a.*						Hands clasped.
66	Right hand, *yu.*						Originally same as No. 58, with No. 34 added.
67	Left hand, *tso.*						Sign for "labor" has been added to this.
68	Friend, *yu.*						Hands extended in friendly greeting.
69	Companion, *p'êng.*						Shuo Wên: "Phoenix." Probably a pair of birds, though many consider it *one only.*
70	Crowd, *chung.*						"Three men," to which an obscure sign was added.

CHINESE IDEOGRAPHS.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
71	Sun, day, *jï.*						Sun, with possibly a sun-spot. Coincides with Egyptian ⊙,○.
72	Moon, month, *yüe.*						"Crescent." *Cf.* No. 131.
73	Stars, *hsing.*						Three stars, to which a phonetic has been added.
74	Morning, *tan.*						Sun just above the horizon.
75	Crystal, *ching.*						Triple sun, as when refracted by a prism.
76	Spring, *ch'un.*						Sprouts and buds started by the sun.
77	Bright, *ming.*						Moon-lit window (or) sun and moon. Probably of double origin.
78	Heaven, sky, *t'ien.*						A sign of obscure meaning, but probably symbolic of deity.
79	*Earth, (as producer), *ti.*						"Earth" 土, and 也 symbol of "female principle." Mother-earth.
80	Earth, soil, ground, *t'u.*						Supposed to be a sprout springing out of the ground.
81	Fire, *huo.*						Rising flames.
82	Metal, *kin.*						Crucibles covered, or intense heat covered, as in smelting.
83	Burn, *fên.*						Trees burning. Two last are variants being "fire" with phonetics.
84	Water, *shui.*						Ripples on water. Coincides with Egyptian ≋.

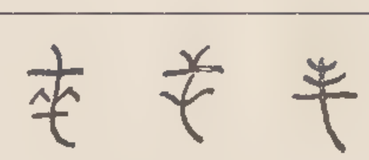
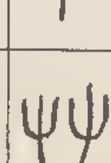
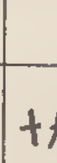
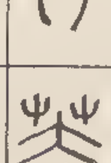
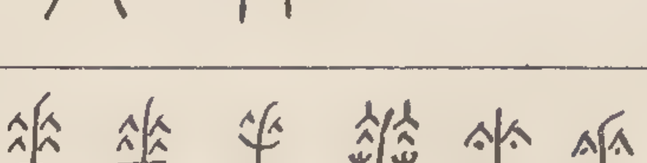
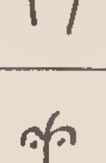
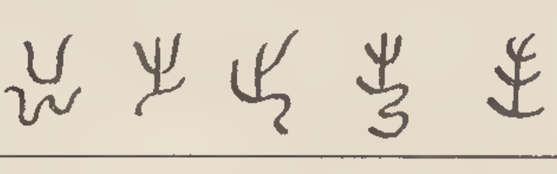
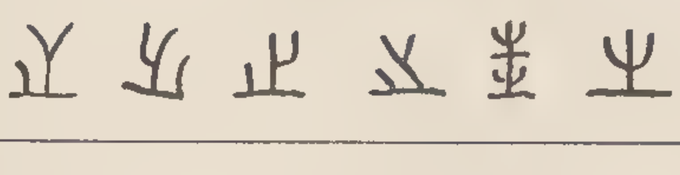
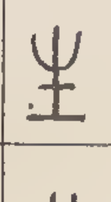
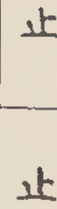
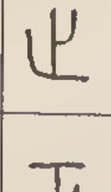
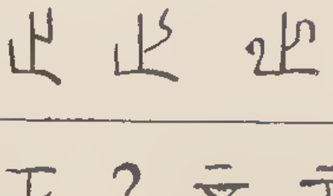
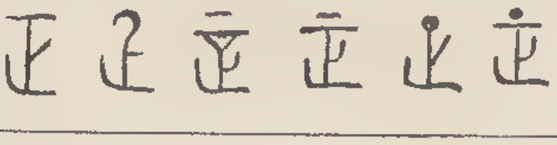
CHINESE IDEOGRAPHS.

*The three last forms are variants based on "earth," "hill," and "water," of obvious significance.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
85	River, *ch'uan.*						〈 "Rivulet." 〈〈 "Stream thirty miles long. 〈〈〈 "River."
86	Ice, *ping.*						Cracks or wrinkles in ice.
87	Water spring, *ch'üan.*						Water issuing from a pool or vent.
88	Pool, abyss, *yüan.*						Picture of a pool, to which the *water* radical has been added.
89	Rain, *yi.*						Rain drops under arch of heaven modified to resemble 天 "sky."
90	Cloud, *yün.*						Wavy clouds with sign 二 "above," altered to 雨 "rain."
91	Thunder, *lei, lui.*						Symbolic of reverberation of thunder. *Rain* radical was added later.
92	Lightning.* *tien*						Thunderbolt, to which "rain" has been added.
93	Hill, *shan.*						Three peaks. *Cf.* Egyptian 𓈙 (a coincidence).
94	Natural mound, *k'iu.*						Eminence smaller than "hill." (*Cf.* No. 93.)
95	Cliff, *han.*						Shuo Wên: "Rock on a hill under which men may dwell."
96	Stone, rock, *shih.*						Perhaps rock-strata, or stone falling from a cliff.
97	Tree, wood, *mu.*						Shuo Wên: "From Ψ plant with roots below. Symbol for all wooden things."
98	Grove, *lin.*						Interlaced branches, simplified into "two trees."

CHINESE IDEOGRAPHS.

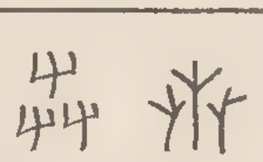
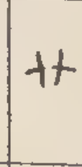
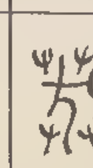
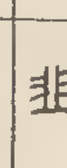
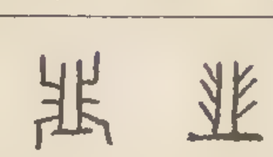
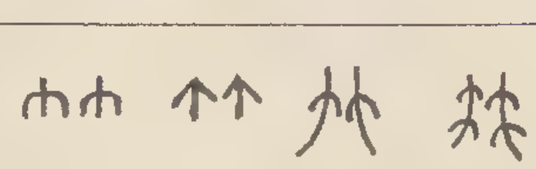
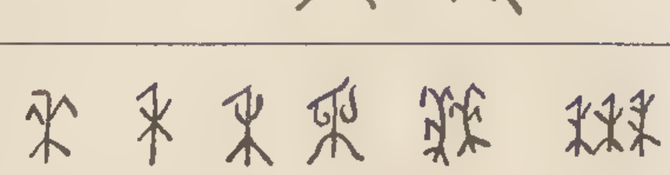
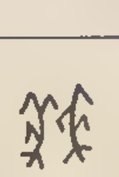
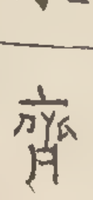
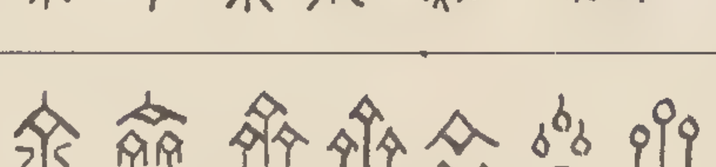
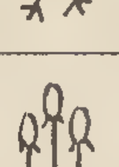
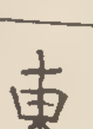
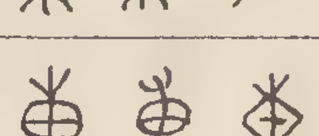
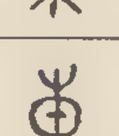
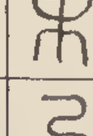
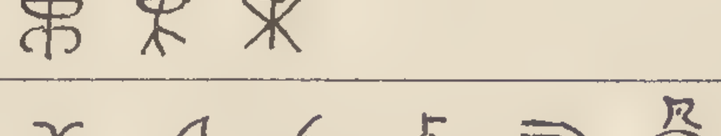
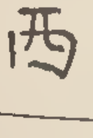
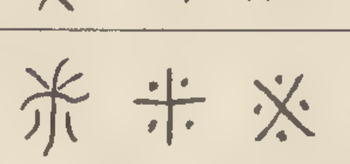
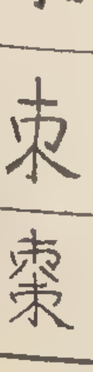
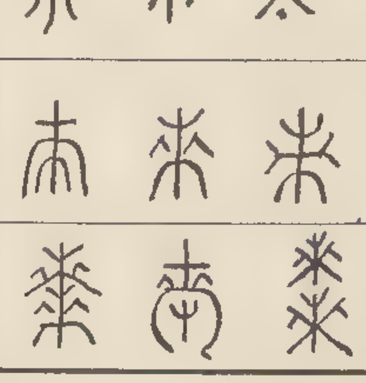
* This is also the original of 神 *shen* "deity." After much research I am inclined to consider these as depicting lightning, which became the sign for "deity" from superstitious dread of lightning. Later the radicals 示 and 雨 were respectively added to distinguish the two meanings.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms	Probable Original.	Remarks.
99	Flowers, *p'i.*						Shuo Wên: "General term for flowers."
100	Outer husk of grass or grain, *fên.*						From Ψ "grass" and sign for husks peeled off.
101	*Thrifty growth, *p'o.*						Obsolete, except in combination.
102	Difficult, *chun.*						Shuo Wên: "Difficult, like a sprout forcing its way through the ground."
103	Plants, *ch'ê.*						Used only in combination. General sign for plants.
104	Grass, leaves, *ts'ao.*						Later enlarged to 蓌, (草), by adding a phonetic.
105	Flower, *hua.*						Picture of a flower, contracted to 艹 and phonetic 化 added. *Cf.* No. 106.
106	Flower, glory, *hua.*						A gorgeous flower. Closely allied to No. 105, but considered, a separate primitive by Shuo Wên.
107	†To issue, *ch'u.*						
108	†Source, of, *chih.*						
109	To produce, to bear, *shêng.*						A sprout further developed than Nos. 107 and 108, as having reached maturity.
110	To stop, *chih.*						Sprout impeded in its growth, hence "stop." Analogous to Nos. 107 and 108.
111	Straight, exact, *chêng.*						Perhaps from "sprout" and "upward." Normal growth. See No. 287.
112	Luxuriant, *fêng.*						A thrifty plant. Related to No. 109.

CHINESE IDEOGRAPHS.

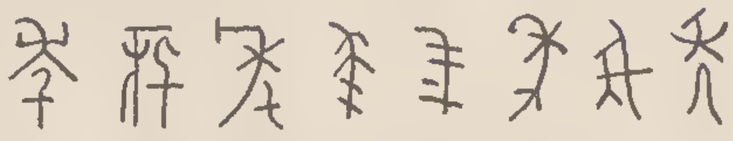
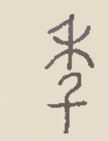
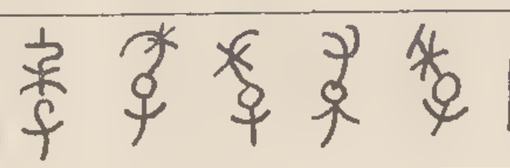
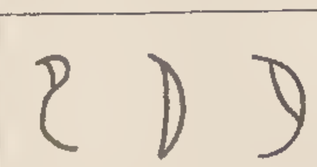
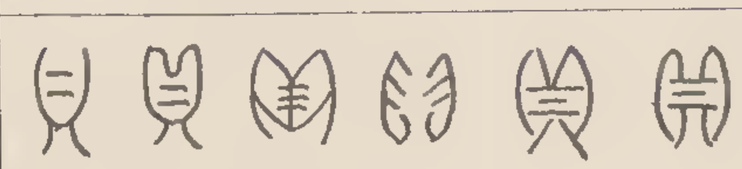
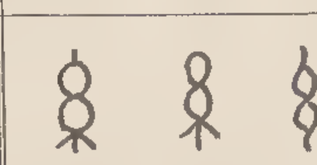
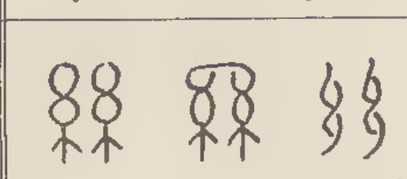
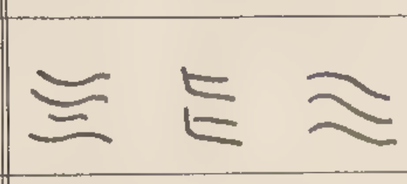
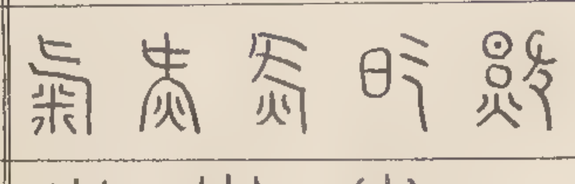
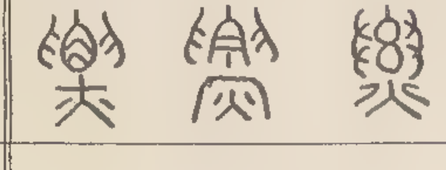
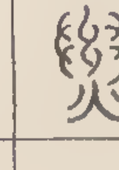
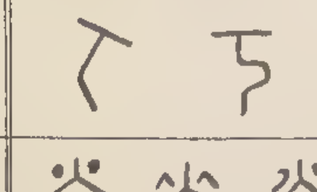
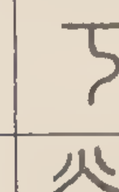
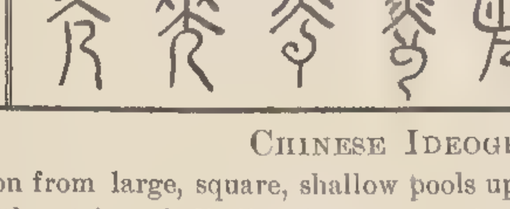
* Resembles No. 100, but Shuo Wên considers it of separate origin.

† These two symbols had a common origin. No. 107 has retained its original sense, *viz.*, "to sprout," "issue." No. 108 has become a possessive sign like "of," derived from the idea "source." Both were originally "a sprout from the ground."

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
113	Herbs, *hui.*						General term for "herbs." No distinguishing feature.
114	Luxuriant, *ying.*						Allied to No. 115, *q. v.*
115	Jungle, rude, *mang.*						"Plants" and "large" repeated, modified to 犬 "dog."
116	* Leeks, *kiu.*						Picture of growing leeks.
117	Bamboo, *chu.*						Pendent bamboo leaves.
118	Growing crops, *hö.*						One or more stalks of grain, with head and leaves.
119	Growing rice or millet, level, *ch'i.*						Row of grain stalks with ripe heads. "Level," from even height of grain.
120	Fruit, result, *kuo.*						Shuo Wên: "Depicts fruit on a tree."
121	East, *tung.*						Sun rising behind a tree.
122	West, *hsi.*						Shuo Wên: "Bird on nest at sunset." Not related to its radical 襾.
123	Landmark, indicator, *piao.*						Clump of mulberry or other bushes to mark bounds of a field.
124	Shelled rice or millet, *mi.*						Depicts *shelled* grain. (Not used of *growing* grain.)
125	Thorn, *ts'i.*						Thorns ⟙ on a tree.
126	Buckthorn, or jujube tree, *tsao.*						Thorn duplicated.

CHINESE IDEOGRAPHS.

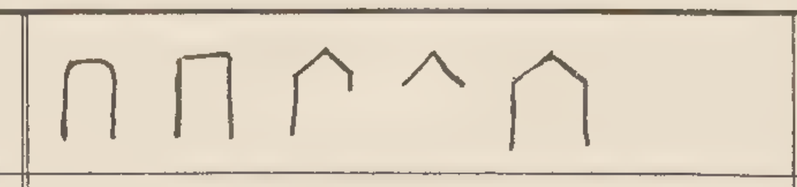
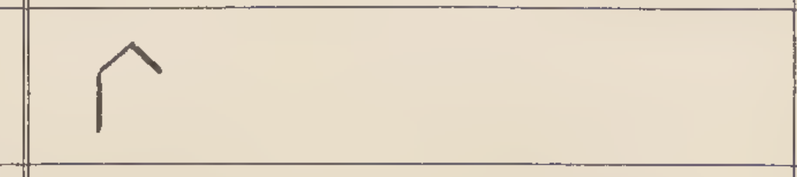
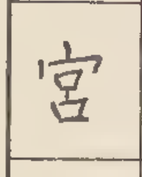
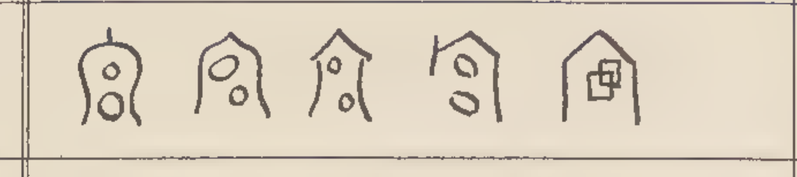
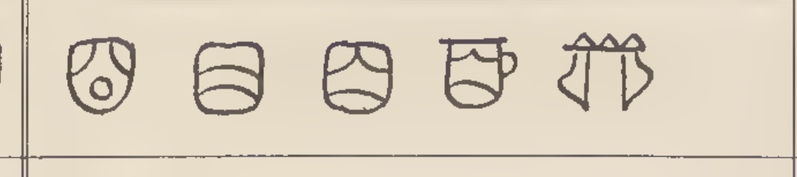
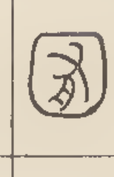
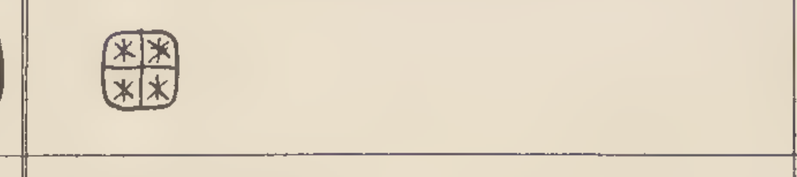
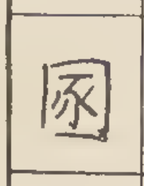
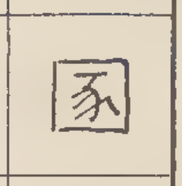
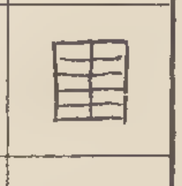
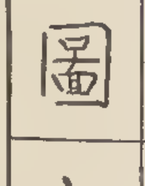
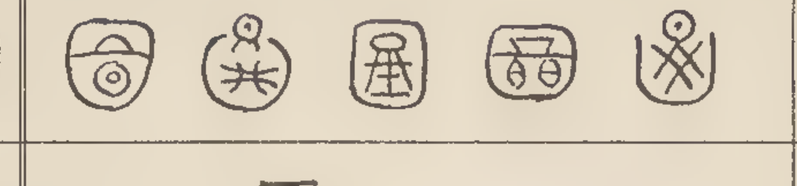
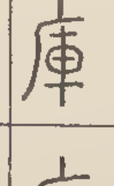
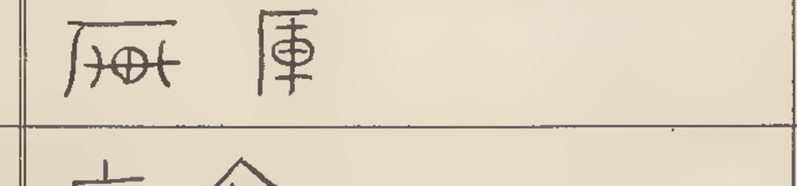
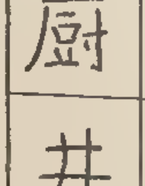
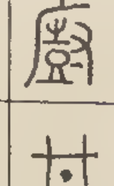
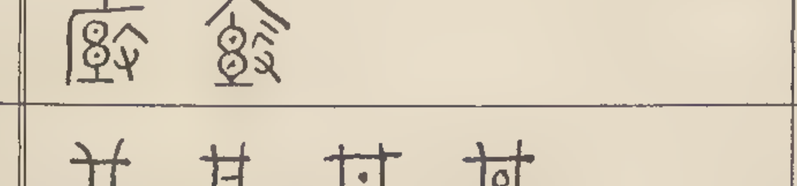
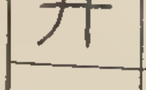
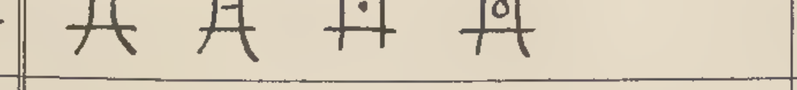
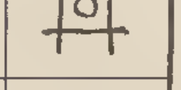
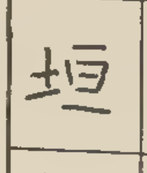
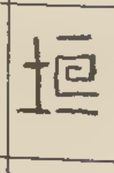
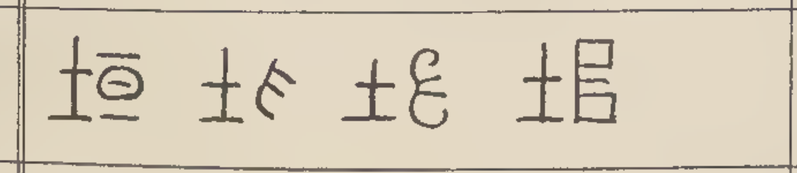
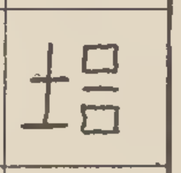
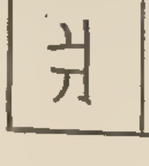
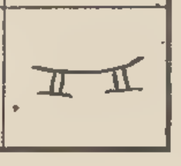
*Shuo Wên puns on this: "A vegetable of *perennial* (kiu) growth, hence called 'kiu.' The form of the plant above the ground."

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
127	Chestnut, *li.*	栗	禾	栗			Chestnut burs on a tree. (Not related to its radical.)
128	Mulberry tree, *sang.*	桑	木	桑			Shuo Wên: "The tree whose leaves silkworms eat." Leaves on a tree.
129	Year, *nien.*	年	干	季			These two signs are closely related, but are obscure in origin. No. 129 may be "crops" and "thousand." No. 130 may be "crops" and "son."
130	Season, *ki.*	季	子	季			
131	Evening, *hsi.*	夕	夕	夕			New moon at evening. *Cf.* No. 72.
132	Shell, value, *pei.*	貝	貝	貝			Bivalve shell. Shuo Wên: "Picture of a sea shell. . . . "Ancients exchanged shells as money."
133	*Salt *lu.*	鹵	鹵	鹵			Earth-basins for evaporating salt.
134	Silk, *mi.*	糸	糸	糸			Twist of silk, or possibly the larva of silk cocoon familiar to the ancient Chinese.
135	Silk thread, *sï.*	絲	糸	絲			Derived from No. 134.
136	Vapor, *k'i.*	气	气	气			Sign suggesting rising vapor.
137	Steam, *k'i.*	氣	气	氣			Steam from *fire* 火, or mist from *sun* ⊙.
138	Signal, ticket, *p'iao.*	票	示	票			Smoke above "fire." Ancient method of signalling in China.
139	†Mirage, *k'ao.*	丂	一	丂			Undulating air.
140	Light, flame, *kuang.*	光	儿	光			"Man" bearing "torch." (Variants show other roots containing "sun" and "fire.")

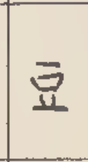
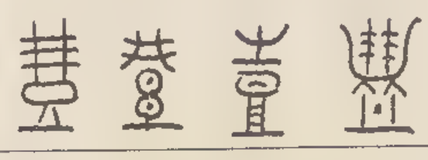
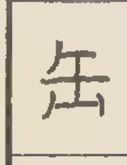
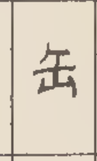
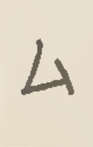
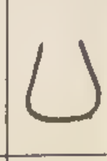
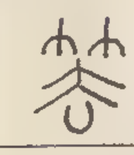
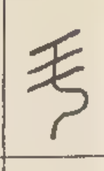
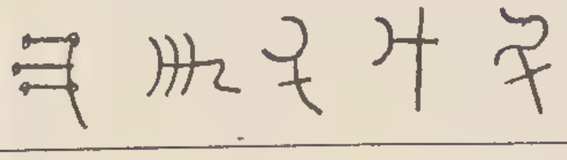
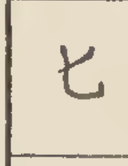
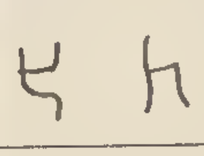
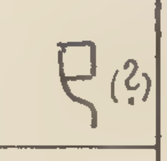
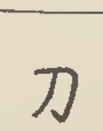
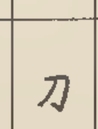
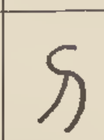
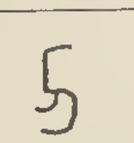
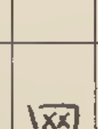
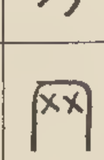
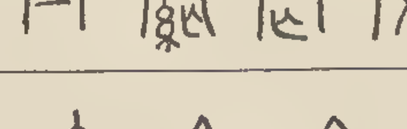
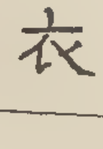
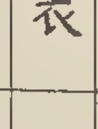
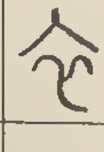
CHINESE IDEOGRAPHS.

*Chinese obtain salt by evaporation from large, square, shallow pools upon the alkali plains. This sign is either a picture of such pools or basins, or possibly suggests a field with patches of alkali. A more complex symbol is now used instead of this.

†Shuo Wên: "Rising air tending to expand, but obstructed as it curls upward."

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
141	Roof, *mien.*						A house. (Used only in combination.)
142	Enclosure, *wei.*						Now written with phonetic added.
143	Shed, *yen.*						Building open on one side.
144	Palace, *kung.*						Hall with steps (or) throne. (Not "two mouths" under "roof," as usually defined.)
145	Window, *kiung.*						Latticed window of varied design.
146	Park, *yu.*						"Field" full of "trees." Now altered, with 有 *yu* as phonetic.
147	Pig-sty, *huan.*						Shuo Wên: "Picture of a pig in a pen."
148	Prison, *yü.*						Shuo Wên: "Prison. Enclosure for criminals." (Shows cells and corridor.)
149	Map, seal, *t'u.*						Sign suggesting a map or diagram. (Embodies No. 338.)
150	Treasury, storehouse, *k'u.*						"Cart" under a "shed."
151	Kitchen, *ch'u.*						"Dish" and other objects, with "hand" under a "shed."
152	Well, cistern, *ching.*						Well with curb.
153	Brick-wall, *yüan.*						Layers of brick, with "clay" ± added, to suggest the material.
154	Bed, *ch'uang.*						Shuo Wên considers this a contraction of 牀, but it is rather the original form.

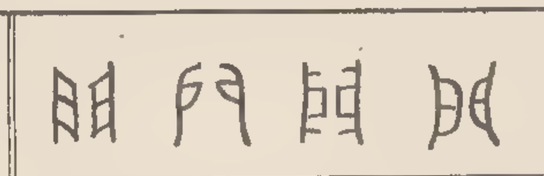
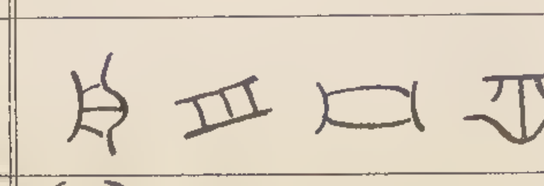
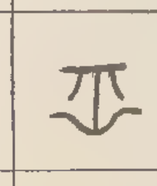
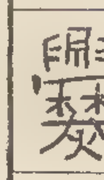
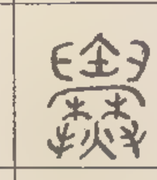
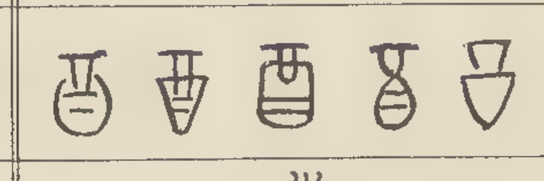
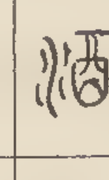
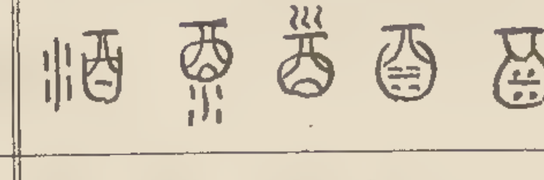
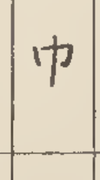
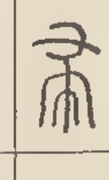
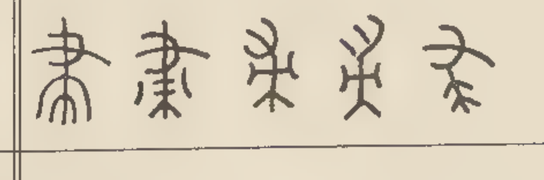
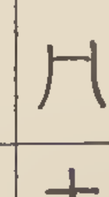
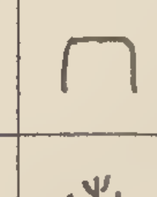
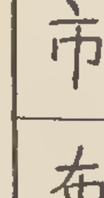
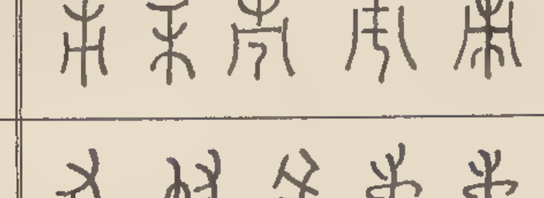
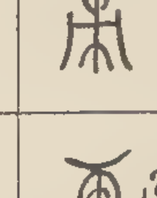
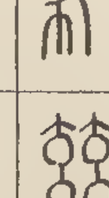
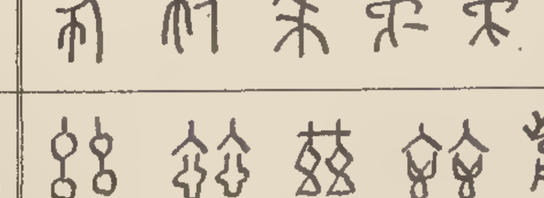
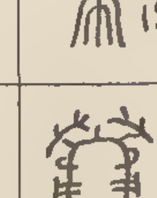
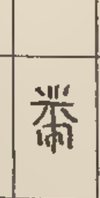
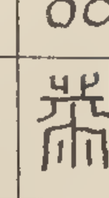
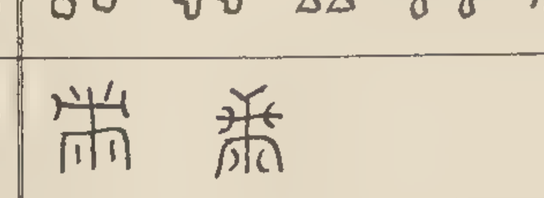
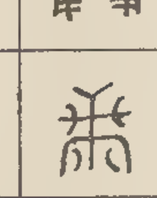
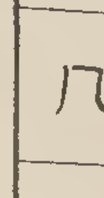
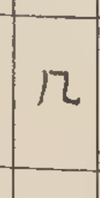
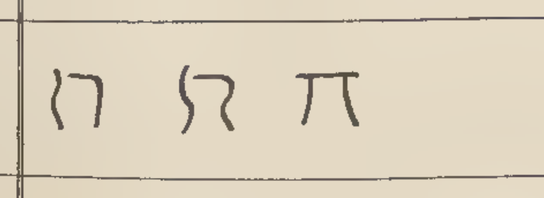
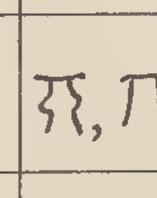
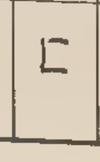
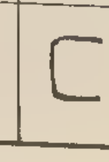
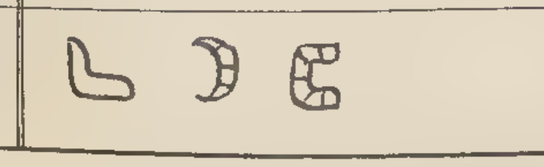
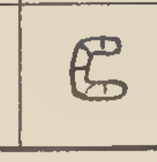
CHINESE IDEOGRAPHS.

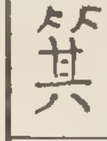
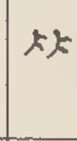
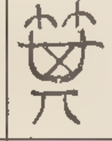
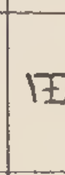
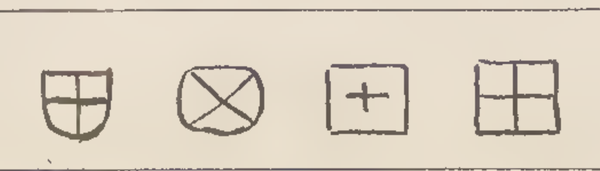
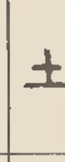
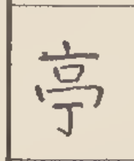
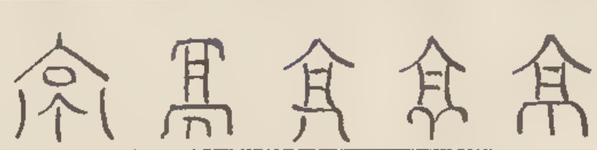
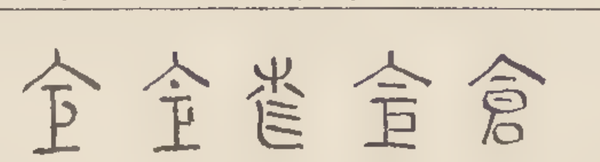
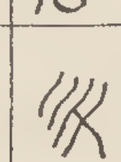
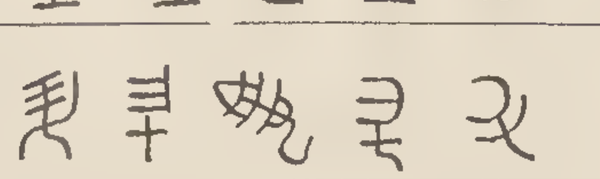
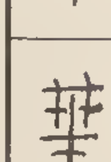
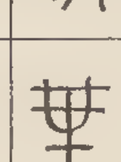
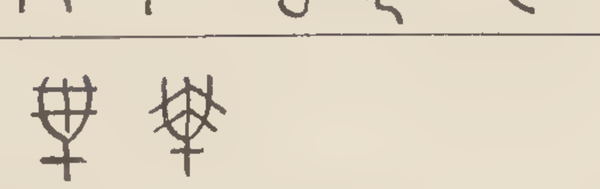
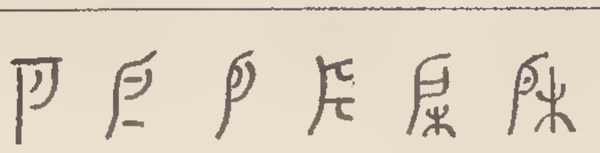
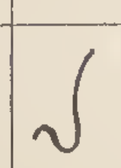
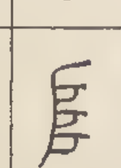
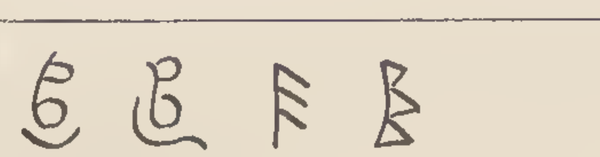
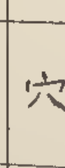
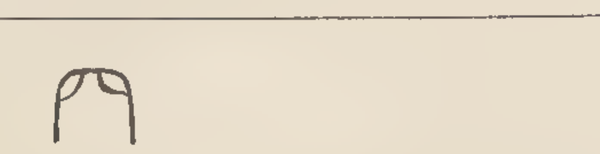
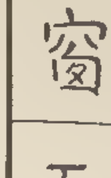
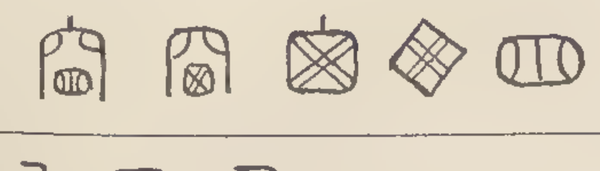
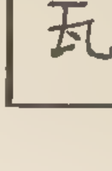
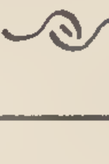
	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
155	Dish, *min.*						A common ancient dish was shaped thus .
156	Stemmed dish, *tou.*						Actual form of the vessel as seen in an exhumed specimen.
157	Sacrificial vessel, *li.*						Vessel with viands or flowers. *Cf.* No. 156.
158	Wine jar, pottery, *fou.*						Wine jar with sealed lid secured by cords (as now in China).
159	Willow basket, *k'ü.*						Shuo Wên: "Picture of a willow cooking vessel." (Distinguish from 凵 *k'an.*)
160	Dipper, *tou.*						Now used to designate "peck measure." *Cf.* No. 188. Originally a dipper.
161	Spoon, *pi.*						Rude outline of a spoon.
162	Cover, lid, *t'o.*						Used only in combination.
163	* Fork, *ya.*						木 "wood" was added and again discarded.
164	Knife, *tao.*						A knife blade.
165	Net, *wang.*						Meshes of a net. Later 亡 was added as phonetic.
166	Cloak, *i.*						Suggests a draped garment.
167	† Cap, *mao.*						
168	Nail, *ting.*						Side view, or head, of nail.

CHINESE IDEOGRAPHS.

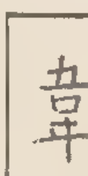
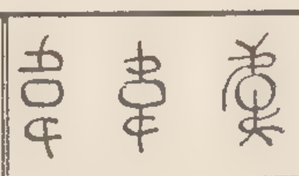
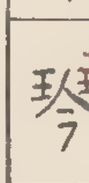
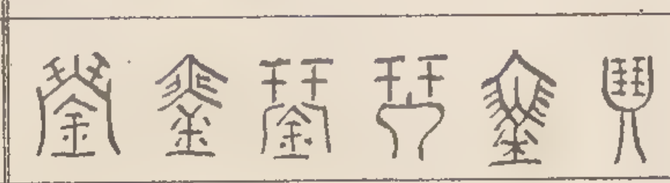
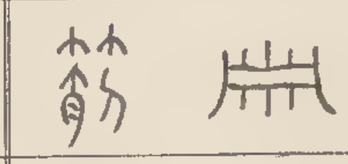
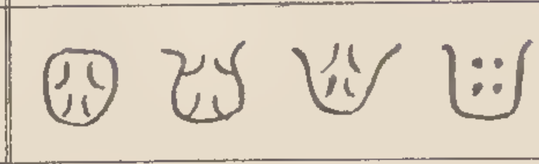
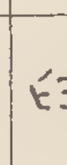
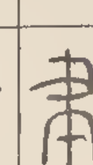
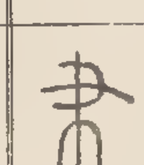
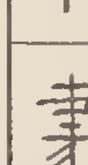
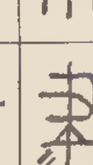
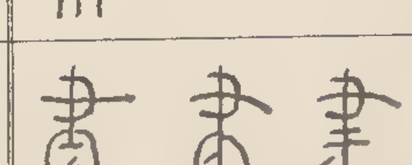
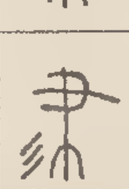
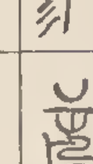
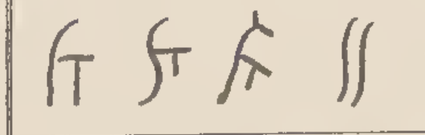
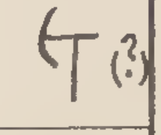
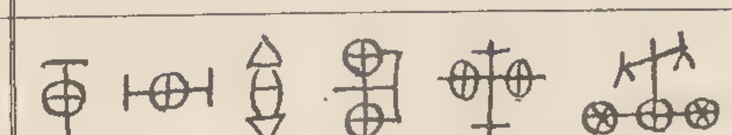
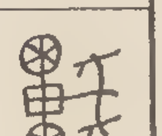
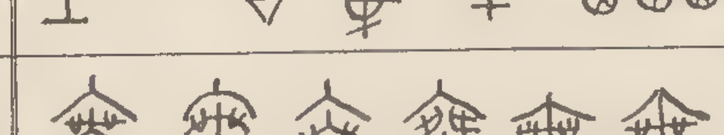
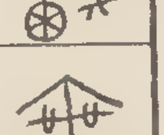
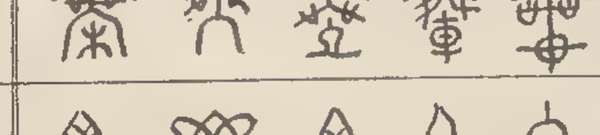
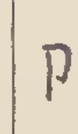
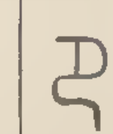
*Now used for "slave girl" by a lewd metonomy.

†Shuo Wên: "Small cap. Headgear of the aborigines." Now supplanted by 帽 "mao," a later mechanical form.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
169	Door, gate, *mén.*						Two-leaved door with bolts and turning posts as now in China.
170	Ship, boat, *chou.*						Either a ship with sail, or deck of boat showing compartments.
171	To cook, *ts'uan.*						Cooking outfit.
172	Wine jar, *yu.*						A kind of amphora. This is now an horary sign.
173	Alcohol, *chiu.*						Jar containing alcohol (clear liquor) signified by 氵 "water."
174	Broom, sweep, *chou.*						Hand grasping broom. (Not related to its radical.)
175	Kerchief, *kin.*						Anciently, a cap or turban worn by aged persons.
176	Curtain, *mi.*						Supposed to be a table cover. Used only in combination.
177	Market, *shih.*						Perhaps from "curtain" and "wood"; a booth, as now in Chinese markets.
178	Woven stuffs, to diffuse, *pu.*						Suggests interlaced threads. Originally applied to silk.
179	Reed mat, *tsï.*						Suggests plaited work. Now an adverb "how," "now."
180	Embroidery, *chih.*						Embroidered design.
181	Small table, *ki.*						Table with straight or curved legs.
182	Receptacle, *fang.*						An obscure form allied to 方 "square" and 匚 "coffer."

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
183	Corn-fan, *ki.*						Winnowing basket held in hands, as to-day in China. *Bamboo* radical has been added.
184	Field, *t'ien.*						Land subdivided.
185	Hall, *t'ang.*						Shuo Wên: "Palace." An imposing edifice.
186	Portico, pavilion, *t'ing.*						Artistic pavilion on pillars, (as now in China).
187	Granary, *ts'ang.*						Large round wicker bins under roof, (as now in China).
188	Pint, *shêng.*						A measure holding 12,000 grains of millet. *Cf.* No. 160. Old exhumed shêng: .
189	Corn-fan, *pan.*						Depicts the implement. Closely allied to No. 183.
190	Um-brella, *san.*						Depicts an umbrella with ribs or decorations.
191	Window, *hu.*						Half of "door." (See No. 169). Variants have "wood" added.
192	Hook, *chüe.*						Form of Chinese fish-hook.
193	Mound, *fou.*						Incongruous symbol for piled earth.
194	Cave, *h'süe.*						Depicts mouth of cave.
195	Window, *ch'uang.*						Latticed window. Originally same as No. 145.
196	Tile, pottery, *wa.*						Perhaps overlapped tiles. Shuo Wên: "General name for kiln-burned ware."

CHINESE IDEOGRAPHS.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
197	Thongs, *wei.*						Knotted thongs. Shuo Wên: "Leather straps."
198	* Lute, *k'in.*						Lute with 5 or 7 strings.
199	† Organ, *hsiao.*						Mouth-organ with 16 or 23 pipes.
200	Grain-mortar, *kiu.*						Shuo Wên: "At first a hole in the ground; later, hollow wood and stone. Form of the vessel with grain inside."
201	Kiln, *kü.*						Obsolete symbol. Depicts compartments of a kiln. (Exact origin is disputed.)
202	Writing brush, *yü.*						Chinese pen or brush held in the hand. *Cf.* No. 174.
203	To write, *chin.*						Pen making marks. Derived from No. 202. Shuo Wên: "Penmanship."
204	Paper kite, *yüan.*						Bird-shaped kite peculiar to China.
205	Axe, adz, *kin*						Shuo Wên: "To chop wood." It may depict chips.
206	Cart, chariot, *ch'e.*						Cart with shaft for horses *abreast*, as anciently in China.
207	Span of horses, ride, *shêng, ch'êng.*						Derived from 206.
208	‡ Turban, *pien.*						Shuo Wên: "Chou dynasty crown, called *pien.*"
209	⁂ Seal, knot, *chie.*						
210	To seal, *yin.*						Hand (claw) affixing a seal.

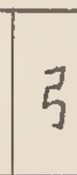
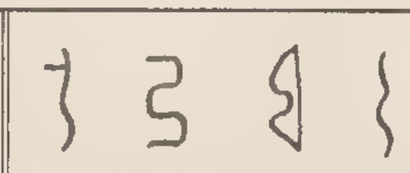
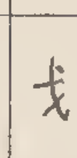
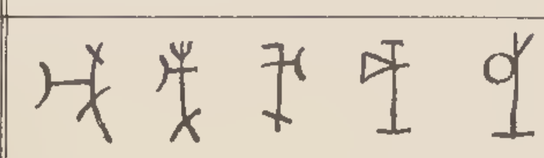
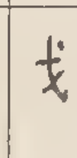
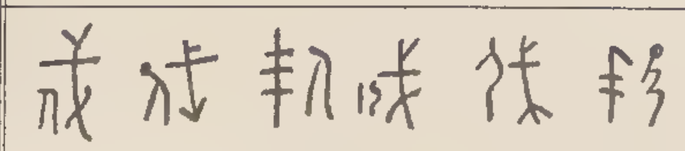
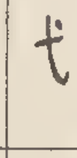
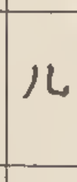
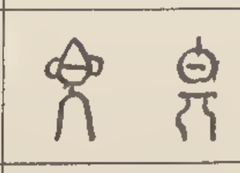
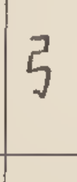
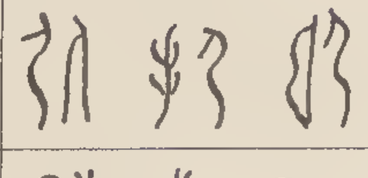
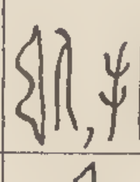
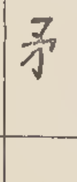
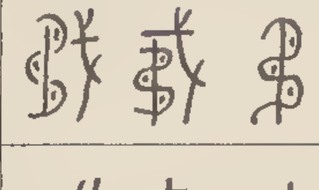
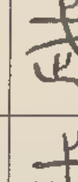
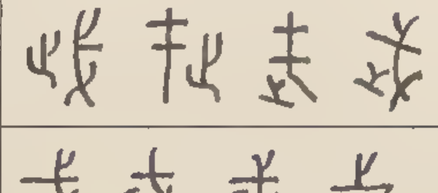
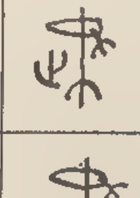
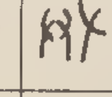
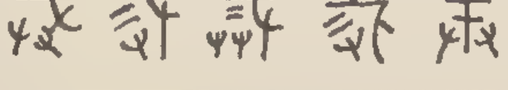
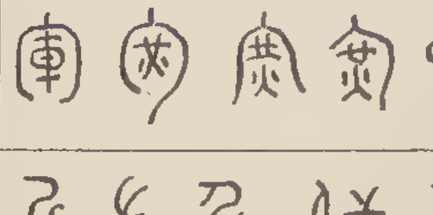
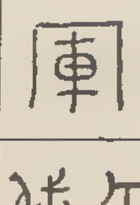
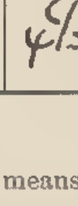
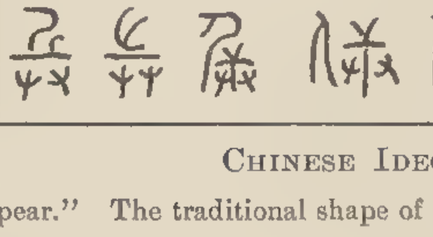
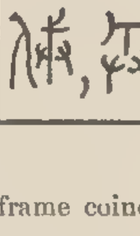
CHINESE IDEOGRAPHS.

* Form of the lute. Lower part was modified to 金 "metal" as phonetic, which has been contracted to 今 kin.

† Originally the form of the instrument, surviving in lower part of the modern symbol. To this "hand" and "bamboo" were added. The variant is 籥 which has "bamboo" and a phonetic "hsiao."

‡ The ornaments below the turban seem to have been altered to 廾 "hands."

⁂ 丯 Chie "knot" is closely allied to this. Shuo Wên defines it as "Sealing knot," referring to the ancient custom of using clay seals and cords. I suspect this depicts a seal of that sort rather than a signet of metal.

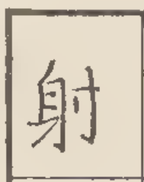
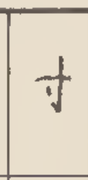
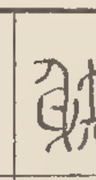
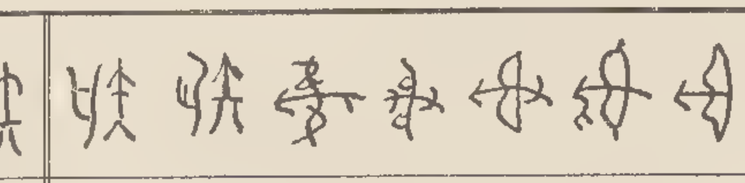
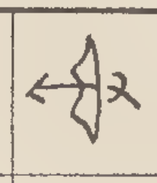
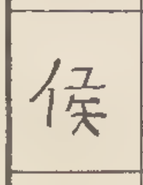
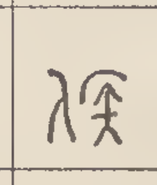
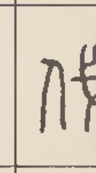
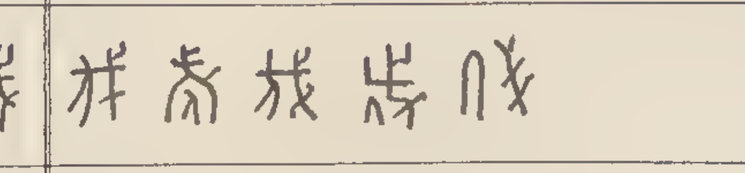
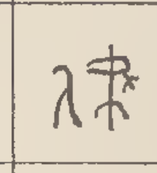
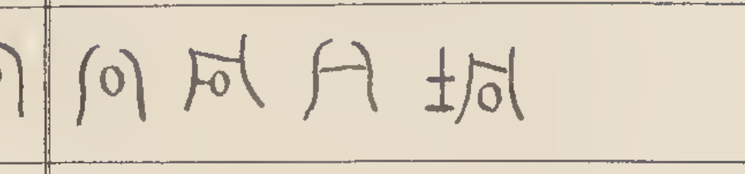
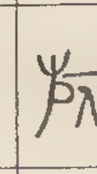
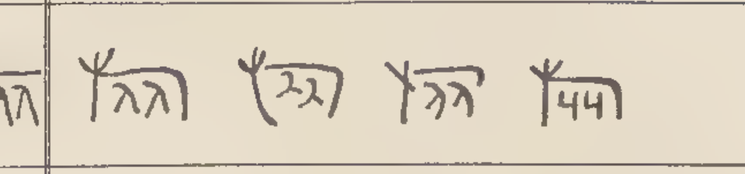
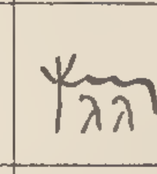
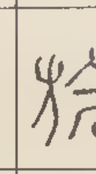
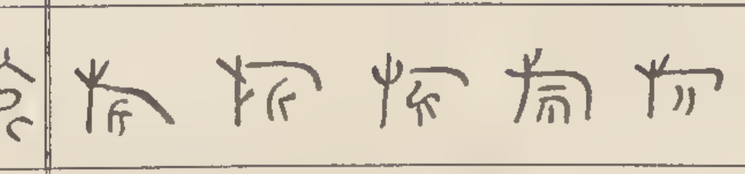
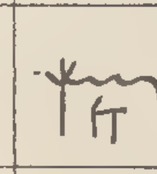
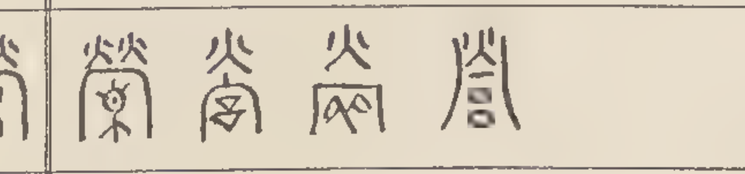
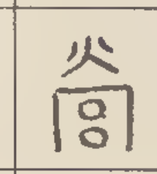
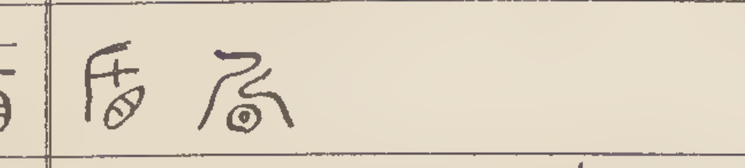
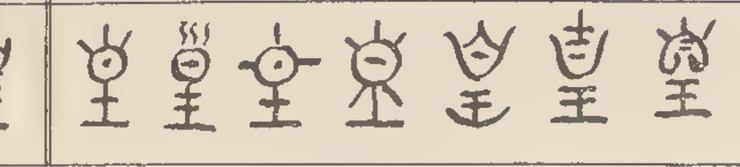
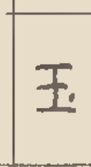
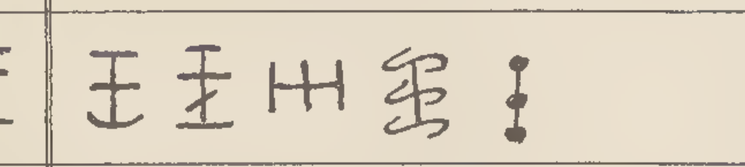
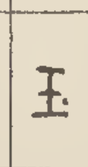
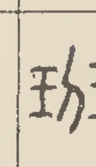
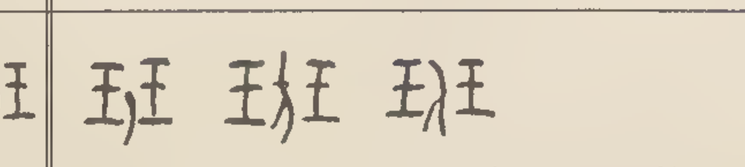
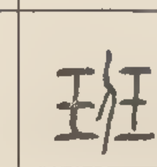
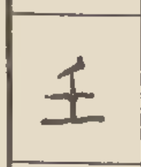
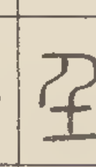
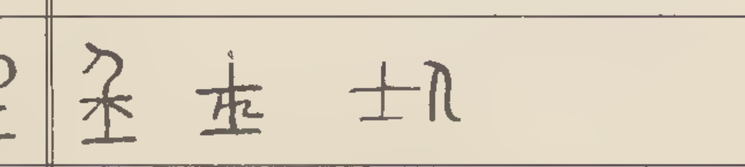
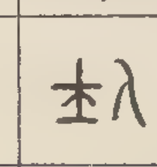
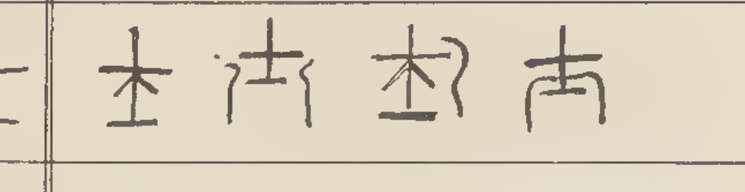
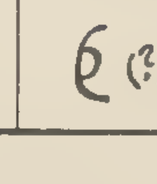
	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
211	Bow, *kung.*						Bow, with or without string.
212	Arrow, *shih.*						Feathered arrow.
213	Halberd, *kuo.*						Ancient bronze-halberd-heads, exhumed in China, show hole for tassel.
214	Battle axe, *wu, mou.*						This symbol is now used as an horary sign.
215	To guard, *shu.*						Soldier (man) with halberd.
216	*Shield, *kan.*						General term for weapons.
217	†Spear, lance, *i*						
218	Helmet, *tou.*						"Man" with head in helmet. Also means "pocket," "keep."
219	To draw a bow, lead, *yin.*						Bow and man, or hand and bow.
220	Three-pronged halberd, *mao.*						Halberd or lance 15 feet long, used by charioteers.
221	Military, *wu.*						"Halberd" and "stop." Shuo Wên: "To lock halberds is *wu.*"
222	Warn, *kiai.*						Shuo Wên: "Two hands grasping halberd. Warn."
223	‡Army, *kiun.*						Chariot in camp.
224	Soldier, weapons, *ping.*						"Man" with "spear" in "hands," or "hands" grasping "axe."

CHINESE IDEOGRAPHS.

* In some connections this means "spear." The traditional shape of ancient shield is the frame coinciding with . I suspect that the symbol also depicts a two-pronged spear.

† By analogy with No. 213, this should depict a lance without hand guard. It now means "arrow" and "shoot," and appears only in combination.

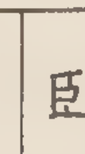
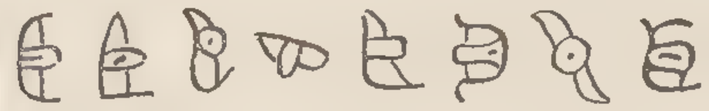
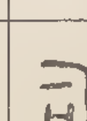
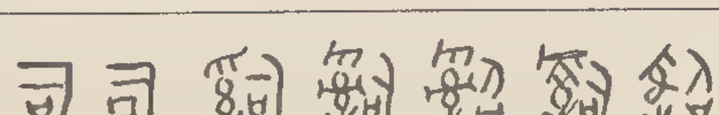
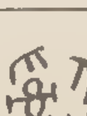
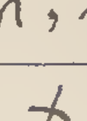
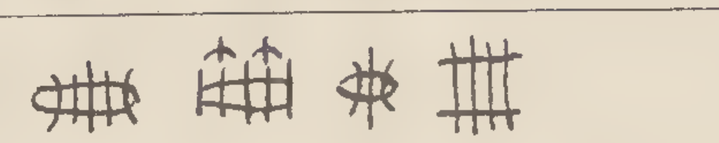
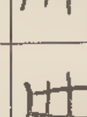
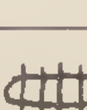
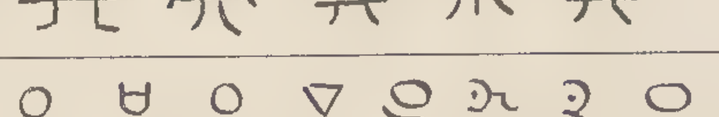
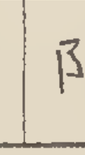
‡ The six last forms are two variants in groups of three forms each. The first is "people" in "camp." The second is of obscure origin.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
225	To shoot arrows, *shê.*						"Hand" drawing a "bow" gradually changed to "body" and "inch."
226	Target, Marquis, *hou.*						Perhaps "arrow" hitting target, to which "man" was added.
227	Destroy, *fa.*						"Man" and "halberd." Same root as No. 215.
228	Frontier, *kiung.*						"Camp" or "guard-house," suggesting frontier.
229	Troops, traveller, *lü.*						"Men" marching under a "banner."
230	Flag, banner, *k'i.*						Depicts floating banner with "axe" beneath. (Significance of "axe" obscure.)
231	Camp, *ying.*						"Fire" and "camp," with tents (?).
232	*Shield, *tun, shun.*					(?)	Symbol of protection for "eyes."
233	Emperor, *huang.*						From "self" and "king," "self ruler," "sole ruler."
234	King, *wang.*						Possibly a string of jade beads, still worn in China as sign of authority.
235	Rank, class, *pan.*						"Knife" and two "jade" objects. Refers to buttons worn to distinguish rank.
236	†Complete, *t'ing.*						"Officer" (No. 237) and "man."
237	Officer, Sir, scholar, *shih.*						Origin obscure. Perhaps allied to 大 "great."
238	Chief, great, *kü.*						Origin obscure. Suggests No. 239.

CHINESE IDEOGRAPHS.

*Shuo Wên: "Shield. Likeness of that with which one protects the body and eyes." The resemblance to a shield is not clear.

† By some chance this has been classed by Chinese lexicographers under 土 "earth" instead of under 士 "officer."

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
239	*Prime Minister, *ch'en.*					(?)	Resembles No. 31 and No. 238. Possibly depicts some insignia of office.
240	Lord, *chu.*						Supposed to be a burning lamp, hence "lord" by metonomy. Suggests No. 234.
241	Father, *fu.*						"Hand" holding "rod" or "scepter." Master of family or class.
242	Retainer, to control, *si.*						Seems to be from "bind" and "summon" 㠯.
243	Ruler, queen, *hou.*					(?)	Reverse of No. 242. Perhaps "summon."
244	Master, *fu.*						"Great" and "man," or "great" doubled, *i. e.*, "very great."
245	To rule, *yin.*						"Hand" holding "scepter." Like No. 241.
246	Scribe, history, *shih.*						"Hand" holding a "stylus." See Fig. 1. (Ancient stylus had ring at end.)
247	†List, record, *ch'ei.*						
248	‡Law, catalogue, *tien.*						Bamboo "records" upon a "table."
249	City (as an official seat), *i*						"Enclosure" and "seal" suggesting official residence. *Cf.* No. 142 and No. 209.
250	City (as a fortress), *ch'êng.*						Composed of Nos. 252, 212, 214. No. 252 has been contracted to "earth," *i. e.*, earth-filled wall.
251	Capital City, *king.*						City gate with tower (as now in China).
252	‽Court inside city gate, *kuo.*						Gate-court with towers over gates at either sides.

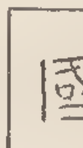
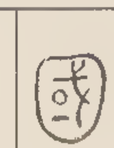
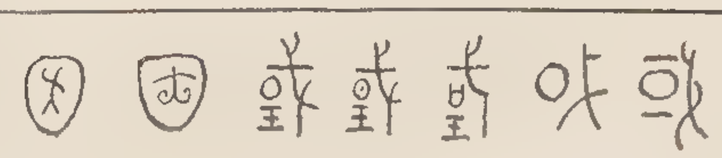
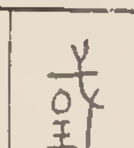
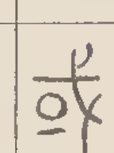
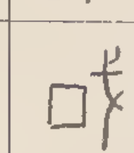
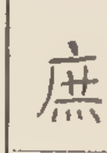
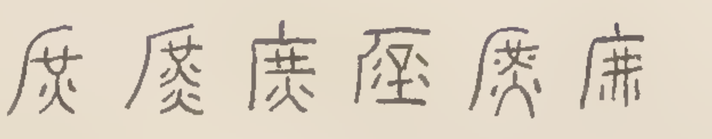
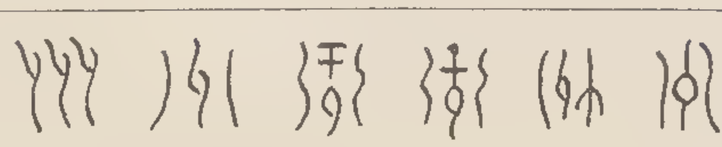
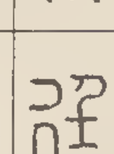
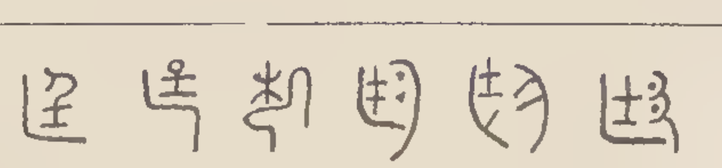
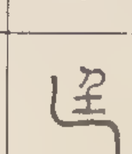
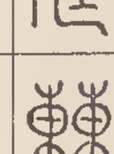
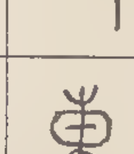
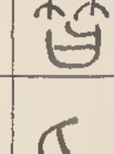
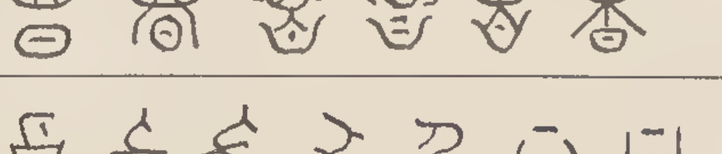
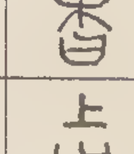
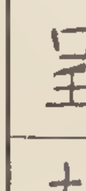
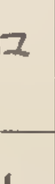
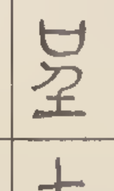
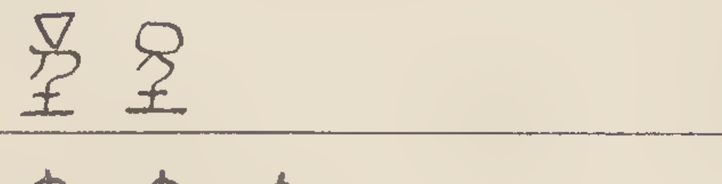
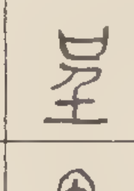
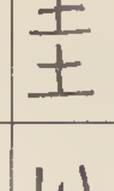
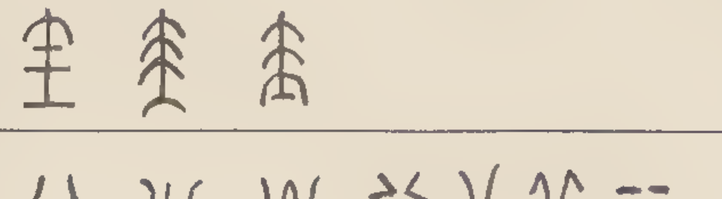
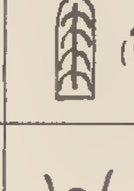
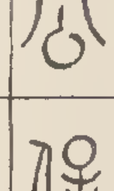
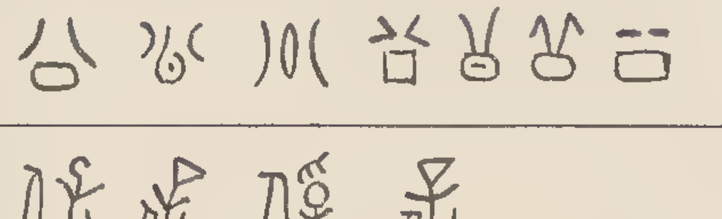
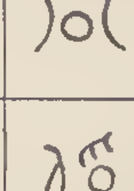
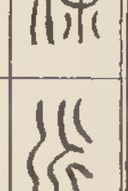
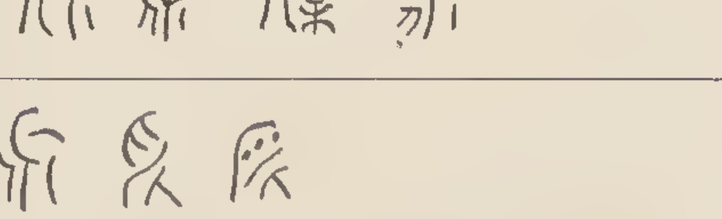
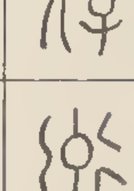
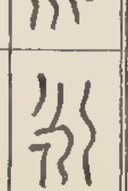
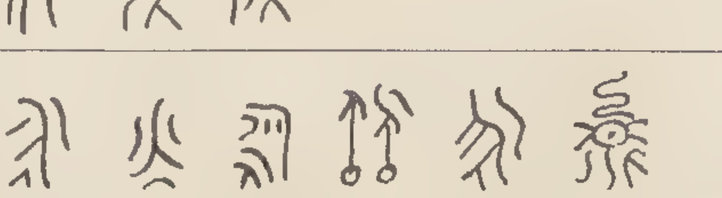
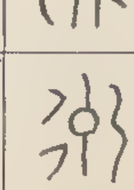
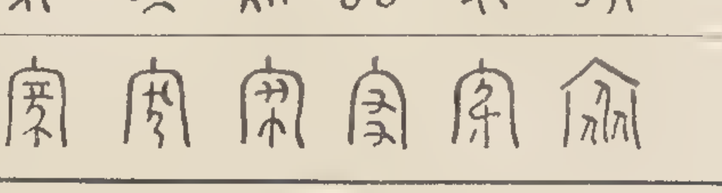
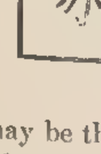
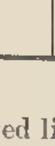
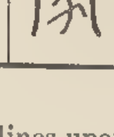
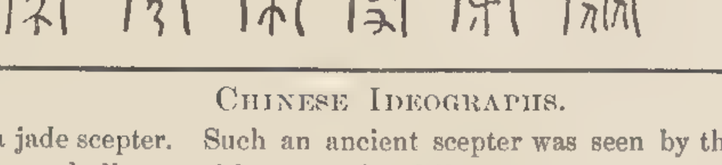
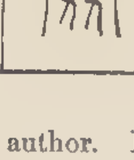
CHINESE IDEOGRAPHS.

* The Chinese notion that this depicts a corpulent man is unsatisfactory.

† Bamboo slips tied with a thong. Shuo Wên says that the slips were of unequal length. Royal degrees were thus filed.

‡ Shuo Wên: "The records of Wu Ti [The Five Rulers B. C. 2597–2255] were given an honored place upon a stand."

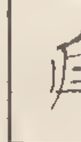
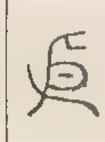
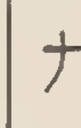
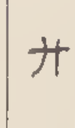
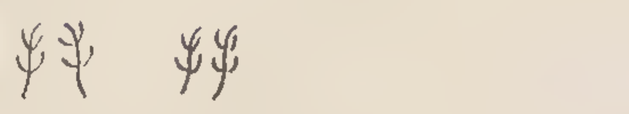
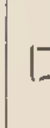
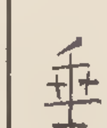
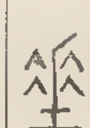
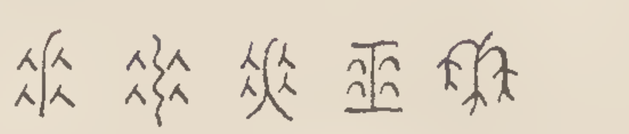
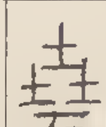
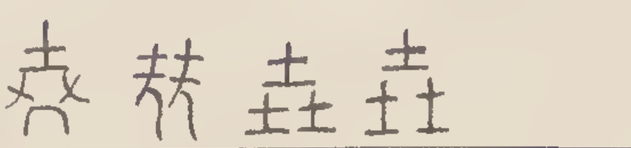
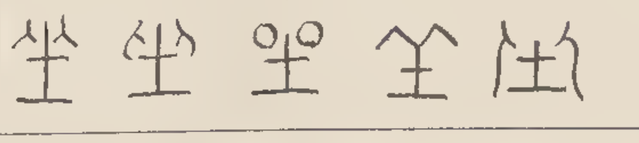
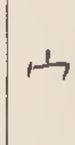
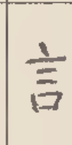
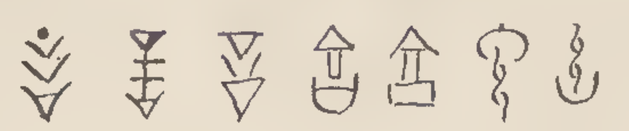
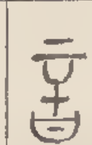
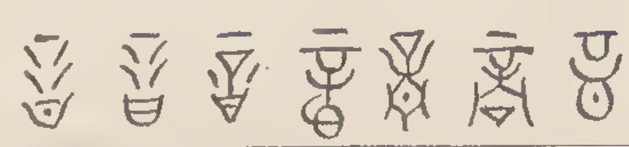
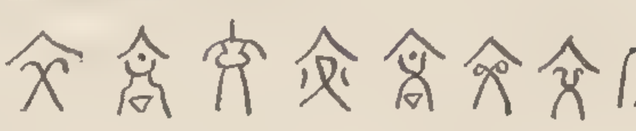
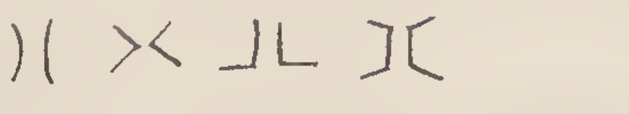
‽ This is now applied to a temple over an arch just inside a city gate.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
253	Nation, *kuo.*						Oldest forms are: "Populace," or, "populace" and "king." Later, "populace," "enclosed," *cf.* No. 254.
254	Populace, *huo.*						"Halberd" and "enclosure." Symbolic of protection over the people.
255	Populace, *shu.*						"Together" and "fire" under a "shed." Symbolic of domestic life.
256	Political district, *chou.*						District between rivers. (Streams were natural boundaries.)
257	Audience hall, *t'ing.*						"Officer" (No. 237) on a "seat." Some forms have "seal" added.
258	Judge of Appeal, *ts'ao.*						"East" and "speak," *i. e.*, Decree from East Palace, the seat of judgment.
259	Decree, *chih.*						"Above" and "speak." Divine or imperial decree. (Not related to its radical.)
260	To inform a superior, *ch'êng.*						"Mouth" and "officer," *i. e.*, speech before a superior.
261	*Scepter, *kuei.*					 (?)	
262	Just, public, *kung.*						Symbol of equal division. "Cut" and an object.
263	Protect, *pao.*						Perhaps "man" rescuing "child" from attack of beast (claw). *Cf.* No. 334.
264	Tribe, clan, *p'ai.*						In form this is the reverse of No. 265. "Streams divided."
265	Perpetual, *yung.*						Water flowing from a pool or spring, hence "constant," "perpetual."
266	†Family, home, *kia.*						Origin obscure.

CHINESE IDEOGRAPHS.

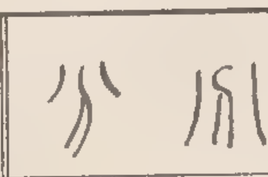
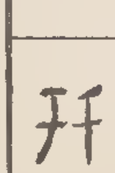
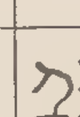
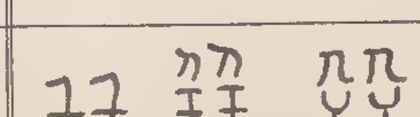
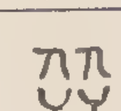
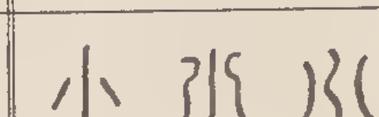
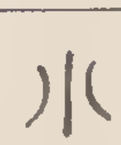
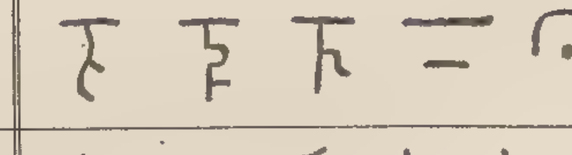
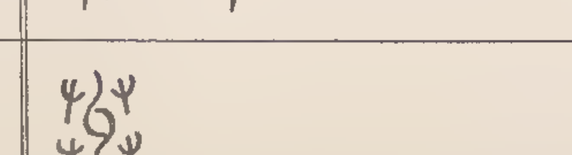
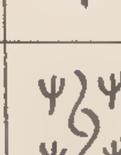
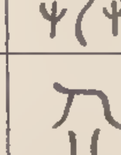
*This may be the carved lines upon a jade scepter. Such an ancient scepter was seen by the author. It was a foot long and two inches wide of the shape pictured above, and engraved all over with conventional lines.

†This may come from different roots. Since the Han Dynasty (circa B. C. 100) it has taken the sole form of "pig" under "roof." Earlier forms show various objects under roof. The most reasonable is "three persons under roof" — a very early form — which I have taken as the probable original.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
267	Look, see, *kien.*						Light issuing from the eye. (In accord with peculiar notion among the Chinese.)
268	Reverse, *i.*						Reversed body, hence to "turn back," obsolete, *cf.* No. 28.
269	Self, *tsï.*						"Nose' (see No. 33). (A Chinaman points to his nose to indicate self.)
270	Fear, excited, *kung.*						Hands raised as in terror. (Used only in combination.)
271	To return, *hui.*						Shuo Wên: "To revolve." Probably a whirlpool, hence "to return."
272	Pendant, *ch'ui.*						A pendant flower, *e. g.*, wistaria.
273	Eminent, *yao.*						"Earth," piled up, hence "high." Later, sign for "platform" was added.
274	Sit, *tso.*						"Two men seated upon the ground"—a common posture in China.
275	Value, precious, *pao.*						"Jade beads," "jar" and "shell" (objects of value) under a "roof." (A good ideograph.)
276	*Speech, *yen.*						Symbolizes words issuing from the mouth, hence speech.
277	*Sound, note, *yin.*						Probably No. 276 ("speech") with "one" added to denote "single utterance" hence "note."
278	Blend, unite, *kiao.*						Blended or united lines. Symbolic of union. *Cf.* Nos. 279 and 338.
279	Mark, sign, *wén.*						Blended lines as in writing. Probably of same origin as No. 278.
280	To cut, *pa.*						Signifies bisection. Coincides with sign for "eight," which may have separate root.

CHINESE IDEOGRAPHS.

*A very interesting pair of symbols. Though the modern forms differ widely, the old forms prove them to be closely related. Shuo Wên considers No. 277 as derived from No. 276 by adding the sign for "one." This should signify a *simple* utterance instead of a *succession* of sounds as in speech. Shuo Wên's further exposition of the relation of thought in the heart to utterance is only confusing, for it must be based upon the doubtful assumption that No. 277 once had the sign for "*heart*" underneath.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
281	To divide, *fên.*						From "knife" (No. 164) and "cut" (No. 280).
282	Like, equal, *pi.*						Two men of *equal* height. Lines were added to strengthen the idea.
283	Level, even, *k'ien.*						Two shields on a level. *Cf.* No. 284.
284	Coördinate, *ping.*						Two "men" on "level" (No. 283). On even footing.
285	Small, *hsiao.*						Stick cut (No. 280) in two, hence "short" "small."
286	Large, great, *ta.*						Probably "man" on "man's" shoulders, or man taller than the average.
287	Up, above, *shang.*						Object *above* a line.
288	Down, below, *hsia.*						Object *below* a line.
289	* Middle, *chung.*						Object or point midway between "up" and "down."
290	† Perpendicular, *kun.*						Shuo Wên: "Up and down equal," as if the halves diverged from a central point.
291	One piece, *kŏ*						Possibly "a single bamboo leaf" (*cf.* No. 117) now expanded to 箇 and 個 with phonetic.
292	Twist, twine, *kiu.*						Either "hands" twisting a "rope," or twining vine with "leaves."
293	Form, individuality, *kiai.*						"Man" and "cut" (No. 280). Suggesting distinctive personality.
294	Together, *kung.*						Four hands united.

CHINESE IDEOGRAPHS.

*The usual explanation of this symbol is an object cut in the middle. This fails to account for the more complex old forms. The most ancient coins have these complex forms, which is strange, in view of the habit of contracting symbols on coins, unless the extra strokes were deemed essential to the meaning. Such I believe was the case, and the idea of a point between "up" and "down" will explain all the extant forms.

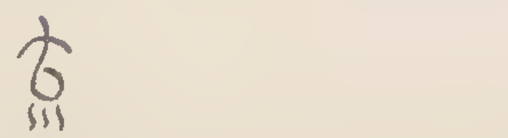
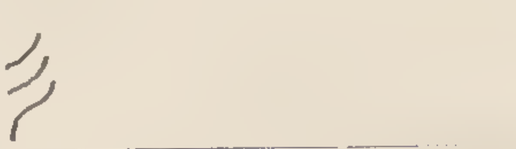
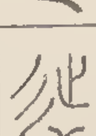
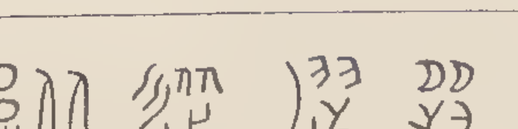
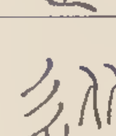
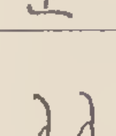
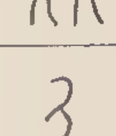
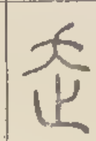
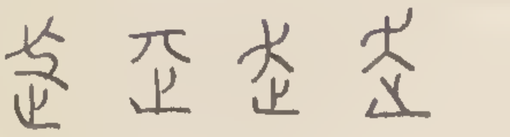
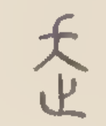
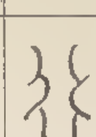
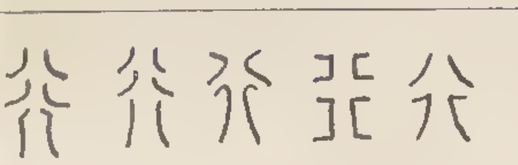
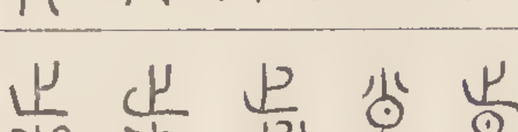
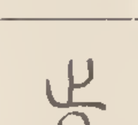
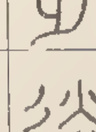
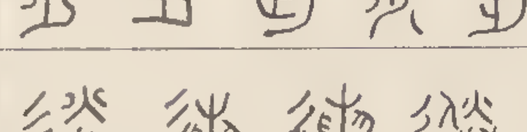
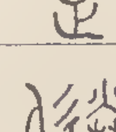
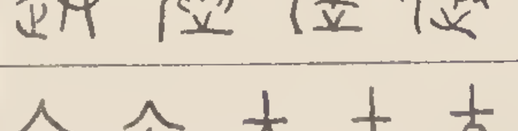
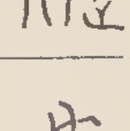
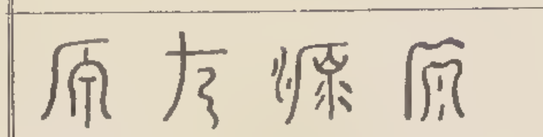
† The original was likely a solid line representing a staff or other vertical object. Shuo Wên's definition is inappropriate, but incidentally accords with the basic idea of No. 289, suggested above.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Form.	Probable Original.	Remarks.
295	*Two, *liang.*	兩	入	兩			Two rooms, or two men in a house. (Obscure origin.)
296	*Ounce, *liang.*	兩	入	兩			One *liang*, *i. e.*, one ounce.
297	†Thirty, generation, *shih.*	世	十	卋			Triple sign for ten, *i. e.*, thirty. A generation is thirty years by Chinese reckoning.
298	†Substitute, generation, *tai.*	代	人	伐			"Man" and "spear," referring to change of watch. (*Cf.* Nos. 215, 227.)
299	Peace, ngan, *'an.*	安	宀	安			One woman in a house. (An essential condition of peace in China.)
300	Fear, *wei.*	危	卩	危			Man standing upon a height (hill), inspires fear. (So Shuo Wên.)
301	Purpose, determination, *chih.*	志	心	志			"Issue" (No. 107) and "heart" (No. 41). Shuo Wên: "That which issues from the heart."
302	Now, this, so, *shih.*	是	日	是			"Sun" or "day" and "exact" (No. 111), hence "now." (So also Shuo Wên.)
303	Noon, *wu.*	午	十	午			Probably a vertical line through roof-gable toward zenith, hence "noon."
304	Half, *pan*	半	十	半		(?)	"Cut" (No. 280) and an obscure sign of varied form.
305	High, *kao*	高	高	高			Tower over city gate. Allied to No. 251, 252.
306	Condole with bereaved, *tiao.*	弔	弓	弔			"Two men" and "bow." Refers to ancient custom of guarding the dead against wild beasts.
307	I, me, *wö.*	我	戈	我			"Hand" and "halberd" (No. 213), vaguely suggesting man's egoism.
308	Bawl, *wu.*	吳	口	吳			"Large" (No. 236) and "mouth." Mouth wide open as in shouting or bawling.

CHINESE IDEOGRAPHS.

*When the sign "liang" (No. 295) was adopted for "ounce" (No. 296), from similarity of sound, the numeral "one" was added to avoid confusion with the original sense of "liang" (No. 295). Later the new form supplemented the old, and now is used for both "ounce" and "two."

†These synonyms for "generation" differ in their original meanings. No. 297 emphasizes the *duration* of a generation," while No. 298 implies *succession*, being originally "change of watch," hence "substitute," < "instead," < "succession," < "generation."

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
309	Curved, bent, *k'ü.*						A bent or knotty piece of wood.
310	Unfilial, *t'u.*	云	厶				"Child" (No. 26) inverted. Abnormal child, hence "unfilial."
311	Steps, walk, *ch'ih.*	彳	彳				Shuo Wên: "Short steps, as man's successive three steps."
312	To run, *cho.*	辵	辶				"Steps" (No. 311) and "stop" (No. 110) suggesting leaps in running.
313	Follow, *ts'ung.*	從	彳				"Man behind man" and "running" (No. 312).
314	Follow, *ts'ung.*	从	人				Man behind man. Variant of No. 313.
315	To move on, *yin.*	廴	廴				Outline of man walking. Shuo Wên: "To keep going."
316	To go, walk, *tsou.*	走	走				"Bend" and "stop" as in walking. Descriptive form of the pictorial sign No. 315.
317	To step, go, *hsing.*	行	行				Foot-prints or motion of one walking.
318	A step, *pu.*	步	止				"Stop" (No. 110) and "foot" (No. 37). The latter has been contracted to an incongruous sign.
319	To escort, *sung.*	送	辶				"Man" "running" (No. 312) with a torch in hand, *i. e.*, torch bearer (as escorting a bride).
320	To stand, *li.*	立	立				Probably "man" standing on the ground.
321	Two abreast, *ping.*	立立	立				Two men side by side.
322	Origin, source, *yüan.*	原	厂				"Spring" (No. 87) under a "cliff" (No. 95), hence, "source."

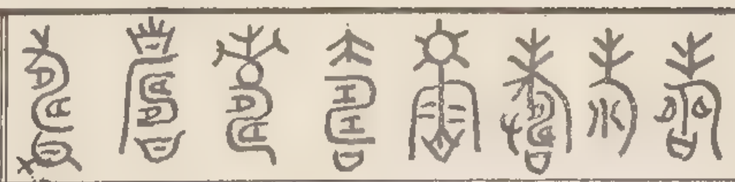
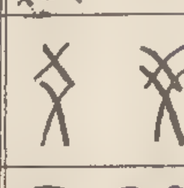
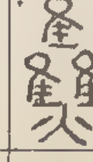
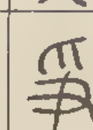
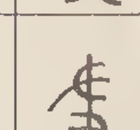
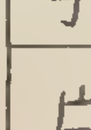
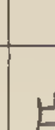
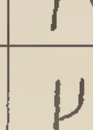
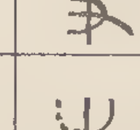
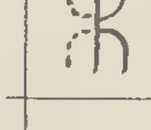
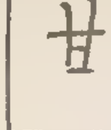
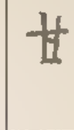
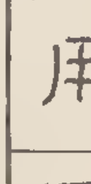
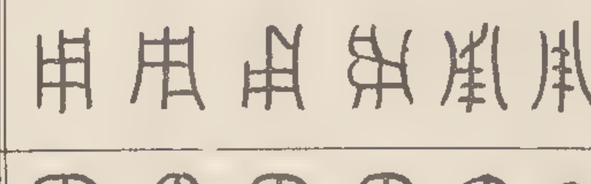
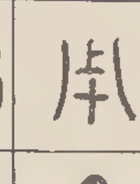
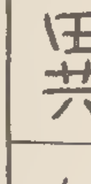
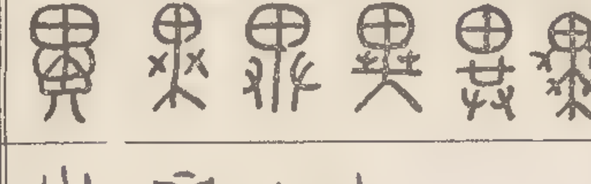
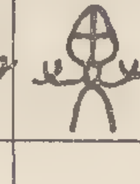
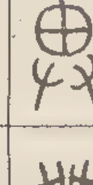
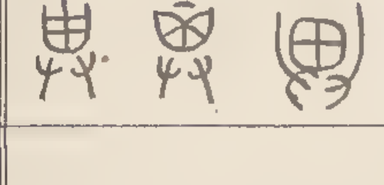
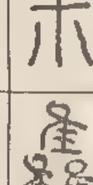
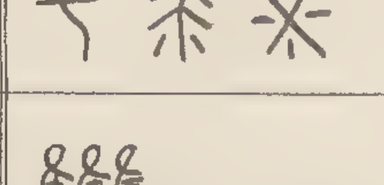
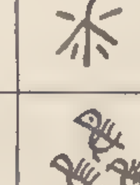
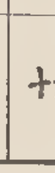
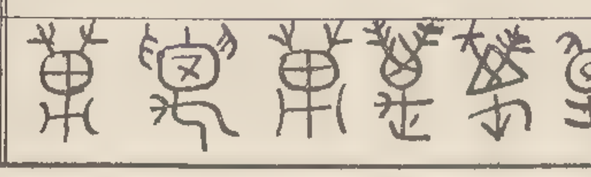
	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
323	Plenty, rich, *fêng.*	豐	豆	豐	豐 豐 豐 豐 豐 豐 豐 豐	豐	"Dish" (No. 156) full of viands, *i. e.*, "grain" (No. 124) and "herbs," offered with "hands." (Like cornucopia).
324	*Large, lofty, *t'ai.*	泰	大	泰	泰 泰 泰 泰 泰 泰 泰 泰	泰	Also 𡎴.
325	*Very, *t'ai.*	太	大	太	太 太 太 太 太 太	太	
326	Enunciate word, sentence, *kü.*	句	口	句	句 句 句 句 句	句	"Twist" (No. 292) and "mouth" referring to motion of lips in speaking.
327	Enclose, wrap, *pao.*	勹	勹	勹	勹 勹 勹	勹	Sign suggesting a wrapper.
328	To wrap up, *pao.*	包	勹	包	包 包 包 包 包	包	Fœtus wrapped in the womb, with "child" added as suggestive sign. (*Cf.* No. 329.)
329	Embryo, *sï.*	巳	巳	巳	巳 巳 巳 巳 巳 巳 巳 巳 巳 巳	巳	Depicts half-formed fœtus before birth. Originally same as 巳 *i.*
330	Tender, young, *yao.*	幺	幺	幺	幺 幺	幺	Seven months' fœtus. Developed from No. 329.
331	Very small, fine, *yu.*	幺幺	幺	幺幺	幺幺 幺幺	幺幺	No. 330 intensified by duplication.
332	Enfold, letter, *han.*	函	凵	函	函 函 函 函	函	Shuo Wên: "Tongue." Possibly tongue in the mouth. *Cf.* No. 56.
333	† Dwell, *kü.*	居	尸	居	居 居 居 居 居 居	居	Man standing in a house.
334	Protect, keep, deposit, *ts'un.*	存	子	存	存 存 存 存 存 存 存 存	存	Hand over child. *Cf.* No. 263. Shuo Wên: "Anxiety."
335	Sheperdess, *kiang.*	姜	女	姜	姜 姜 姜	姜	"Sheep" and "woman." "Sheep-woman."
336	‡ To string, connect, *kuan.*	貫	貝	貫	貫 貫 貫 貫 貫 貫 貫	貫	String of shells.

CHINESE IDEOGRAPHS.

* For full explanation see page 14.

† The evolution of the modern form may be thus : 居<𠂤<𠂤<居<居<居. This theory is strengthened by the survival of a variant 𠂤.

‡ The ancient custom of stringing shells as money may account for the traditional habit of stringing coins in China.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
337	*Longevity, age, *shou.*						Shuo Wên: "Enduring, following."
338	Blend, diagram, *yao.*						Blended lines. Related to Nos. 278, 279, *q. v.*
339	Singe, scorch, *chiao.*						One or more birds over fire. Also tortoise over fire.
340	Wrangle, *chêng.*						Hands opposed, or struggling for a staff or spear.
341	†Splinter, *p'ien.*						Shuo Wên: "Split wood. From half of tree."
342	Sweet, *kan.*						Possibly palatable (sweet) food retained in the mouth.
343	Bitter, *hsin.*					(?)	Origin obscure. Refers to melancholy of autumn.
344	To use, *yung.*						Significance obscure.
345	Strange, unlike, *i.*						Ghost or other strange figure. Allied to No. 354.
346	Lift, raise, *ki.*						Hands lifting a weight.
347	Opposed, perverse, *ch'uan.*						Supposed by Chinese to be two men lying back to back (a guess).
348	Spread out, sort out, *pien.*						Depicts beast's claw outspread.
349	Together, market, *chi.*						Three birds on a tree. (Now contracted.)
350	Myriad, *wan.*						Some prolific creature like the frog or scorpion. (Not related to its radical.)

CHINESE IDEOGRAPHS.

*A very complex symbol of many forms. It seems to be composed of 老 *lao* "old," 永 *yung* "perpetual" and 口 *k'ou* mouth. The significance of the two first is apparent, but that of "mouth" is obscure.

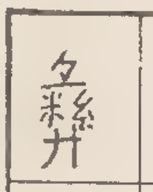
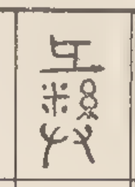
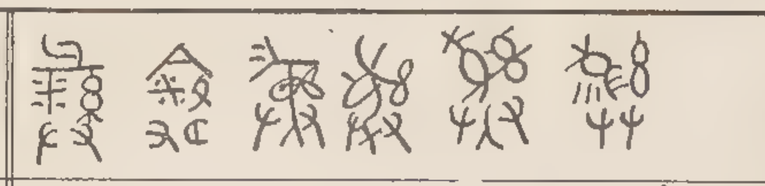
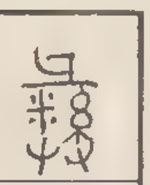
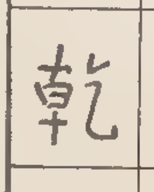
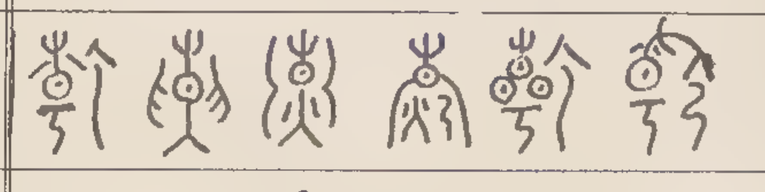
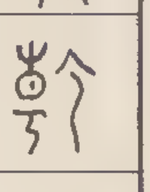
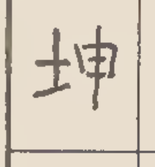
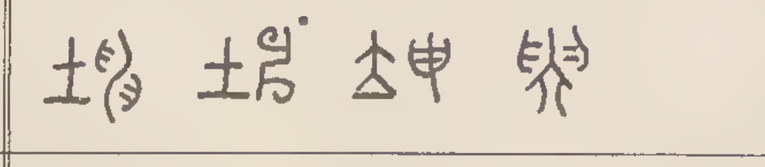
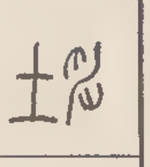
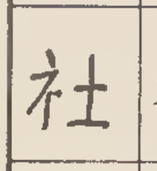
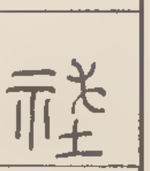
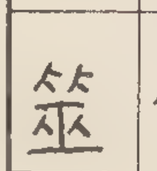
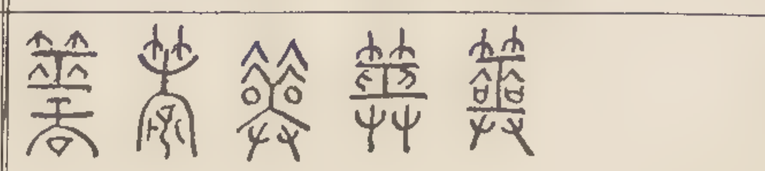
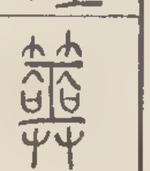
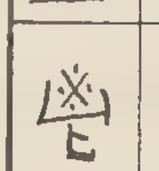
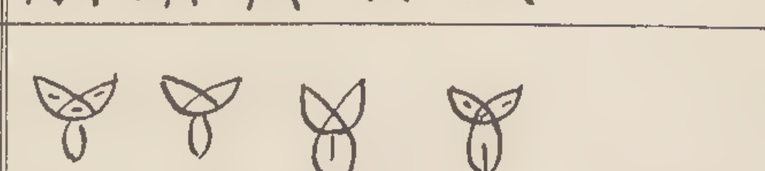
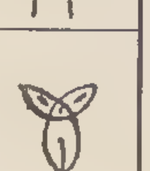
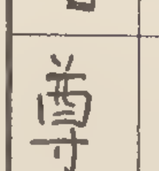
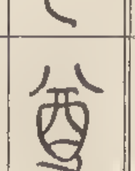
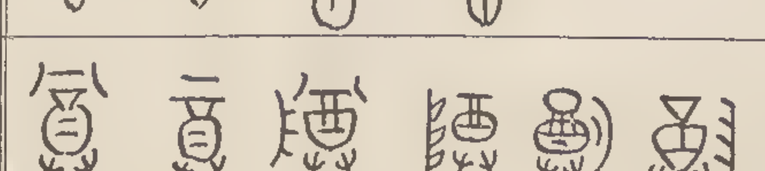
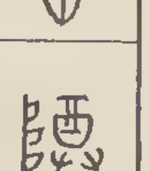
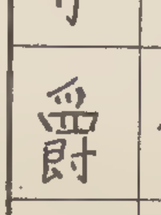
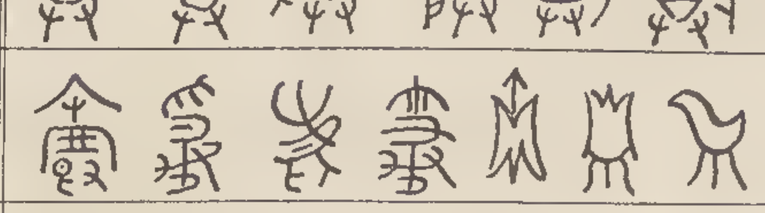
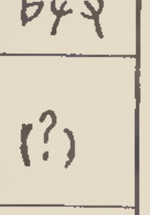
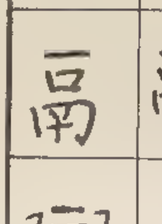
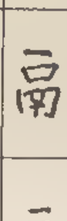
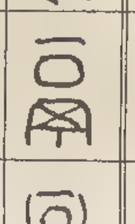
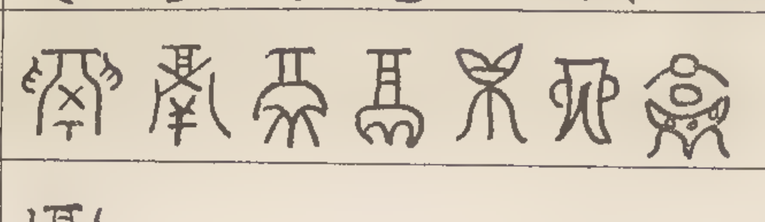
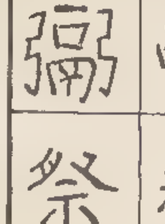
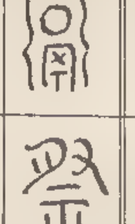
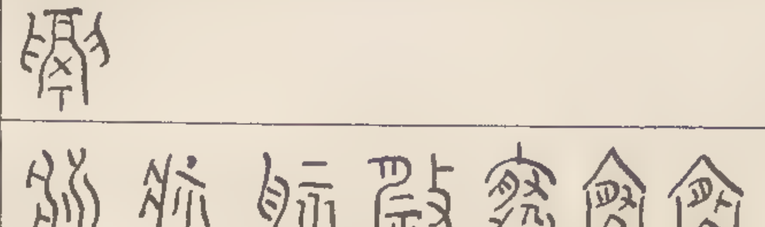
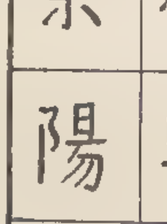
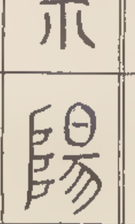
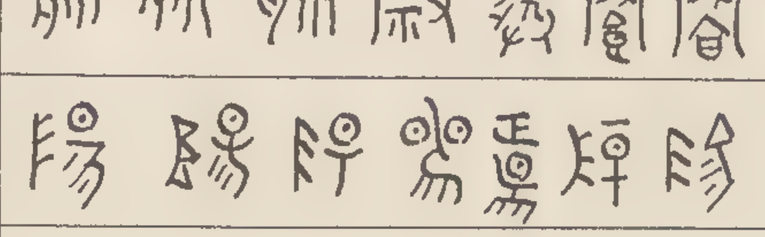
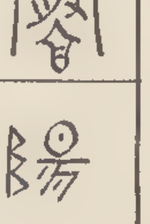
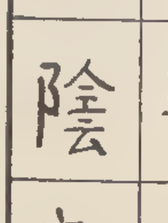
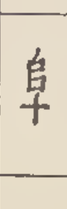
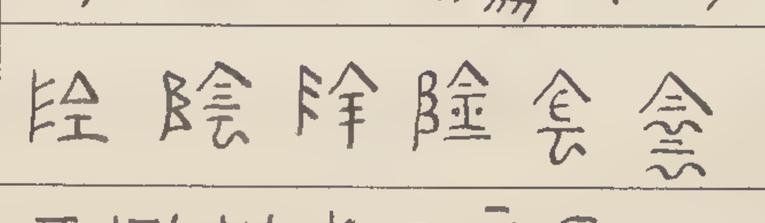
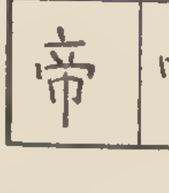
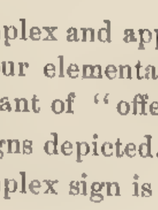
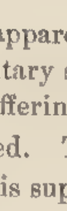
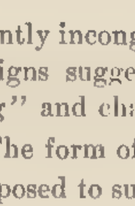
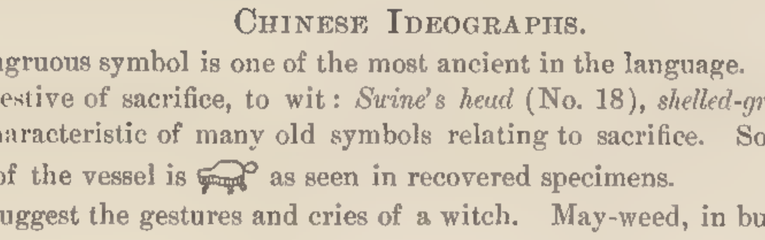
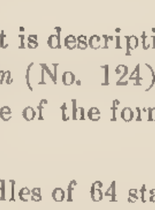
† Mechanically derived from the sign for "tree" (No. 97). Not the reverse of "bed" (No. 154), as often hastily inferred.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
351	Diety, gods, *shen.*	神	示	神		(?)	(See note under No. 92.) Symbols found with or without sign for "heavenly influence" (No. 353) as radical. Used both as noun (deity) and adjective (divine, spiritual).
352	Lightning (?), (original of No. 351, *q. v.*)	申	田	申		(?)	
353	*Heavenly influence, edict, *sï.*	示	示	示		示	
354	Demon, *kuei.*	鬼	鬼	鬼		鬼	Form of man with sign for "mystery" affixed. *Cf.* No. 345.
355	Ancestral temple, *tsung.*	宗	宀	宗		宗	"Edifice" with "heavenly influence" within.
356	Sacrifice, ancestor, *tsu.*	祖	示	祖		且	Symbol of sacrifice (grave, piled cakes, or vessel) to which "heavenly influence" was added.
357	Filial, *hsiao.*	孝	子	孝		孝	Shuo Wên: "One who piously treats his father and mother. From 'old' and 'son,' The son supports the aged."
358	Thank offering, enjoy, *hsiang.*	享	亠	享		享	Covered jar used in thank offerings. Originally same as No. 359.
359	To pervade, *hêng.*	亨	亠	亨		亨	Shuo Wên rightly considers this the same as No. 358. (Variant 喜 still used.)
360	Omen, *chao.*	兆	儿	兆		兆	Supposed to be lines on tortoise-shell, used in divination.
361	†To divine, *pu.*	卜	卜	卜		卜	Perhaps related to No. 360.
362	To enquire by divination, *chan.*	占	卜	占		占	"Mouth" and "to divine" (No. 361). Sometimes enclosed in sign of obscure meaning.
363	Sacrificial tankard, *yu.*	卣	卜	卣		卣	Depicts tankard, with No. 361 added.
364	†Incense-tripod, *ting.*	鼎	鼎	鼎		鼎	Shell (No. 132) with legs.

CHINESE IDEOGRAPHS.

*Shuo Wên: "That which comes from Heaven as revealing fortune or misfortune to men. From 二 and ||', sun, moon and stars descending. Pertains to astrological scrutiny into divine affairs." The horizontal lines may be the sign for "above" (No. 287), or a special sign for Heaven. The vertical lines depict the descending influences.

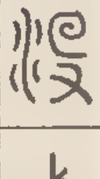
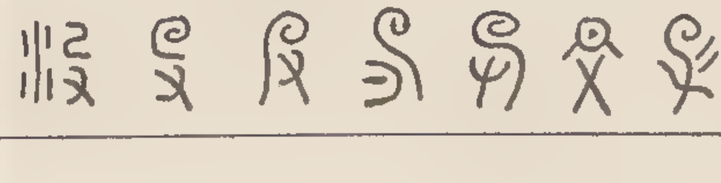
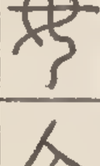
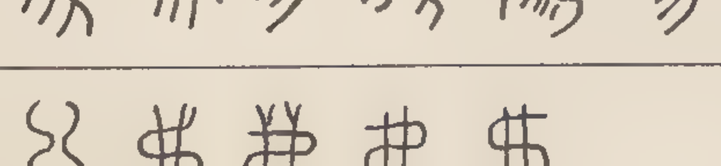
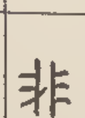
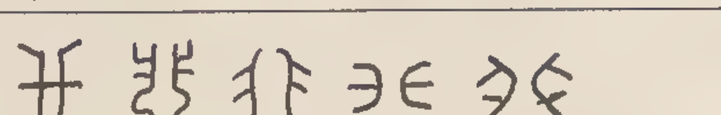
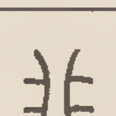
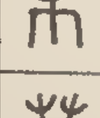
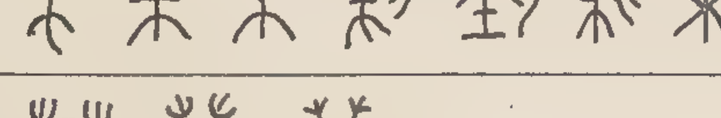
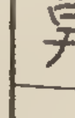
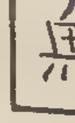
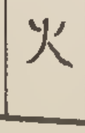
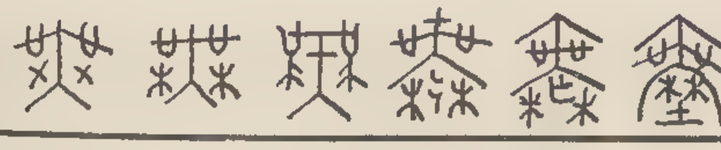
† Common form of the tripod is 鼎, which may be from the original use of a horned shell for holding incense, as for instance 鼏.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
365	*Sacrificial bowl, *i.*						Shuo Wên calls this a vessel for ancestral worship.
366	Celestial, superior, *k'ien, kan.*						Mystic symbol composed of elements pertaining to heaven, sun, air, or fire, and meteoric influence.
367	Earthly, inferior, *k'un.*						"Earth" and "God" (No. 351) contracted, *i. e.*, "earth-deity." Opposite of No. 366.
368	Tutelary-deity, *shê.*						"Heavenly influence" (No. 353) over nature (trees and earth). Shuo Wên: "Earth-lord."
369	† To divine by witchcraft, *shih.*						Shuo Wên: "Mystic changes in nature as detected by the use of May-weed."
370	Spirit, *ch'ang.*						Weird sign for a ghost.
371	Venerate, honorable, *tsun.*						"Hands" offering "sacricial jar" before a "mound" (grave). (Last has been discarded, and "hands" changed to sign for "inch.")
372	Tripod cup, rank, *chüe.*						Descriptive and pictorial signs relating to use of the libation cup "chüe."
373	Large measure, urn, *li, kê.*						Depicts large tripod with handles, used in temples.
374	(Variant, of last), *li.*						The two signs at sides are the handles, altered to "bow" (No. 211).
375	To sacrifice, *chi.*						"Hand," "flesh" and "jar" in a "temple." Last is now discarded and "jar" altered.
376	Active or male principle, *yang.*						Shuo Wên: "High, light. Superior forces of nature."
377	Passive or female principle, *yin.*						Precise significance of this and No. 376 is not clear. They refer to geomantic condition, hill, sun, cloud, etc.
378	Supreme Ruler, *ti.*						Shuo Wên: "To judge. Title of the universal ruler." (Used of emperor and deity.)

CHINESE IDEOGRAPHS.

*This complex and apparently incongruous symbol is one of the most ancient in the language. It is descriptive rather than pictorial, being composed of four elementary signs suggestive of sacrifice, to wit: *Swine's head* (No. 18), *shelled-grain* (No. 124), *silk* (No. 134) and "*hands*," the last significant of "offering" and characteristic of many old symbols relating to sacrifice. Some of the forms are in ancient script which obscures the signs depicted. The form of the vessel is as seen in recovered specimens.

† This complex sign is supposed to suggest the gestures and cries of a witch. May-weed, in bundles of 64 stalks, is still used by Chinese in divination.

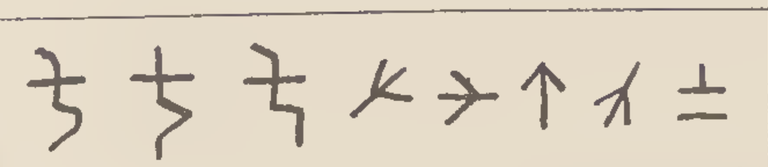
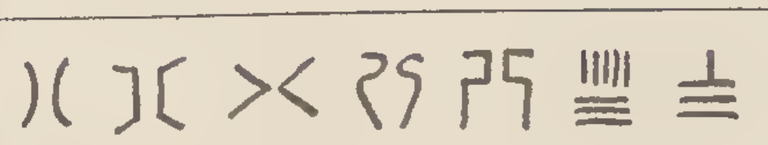
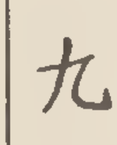
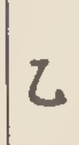
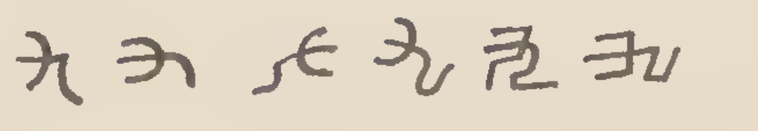
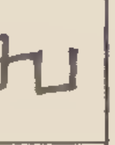
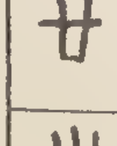
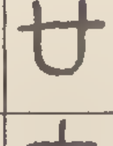
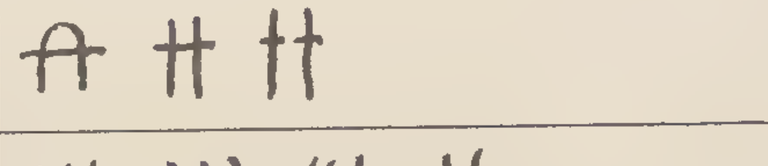
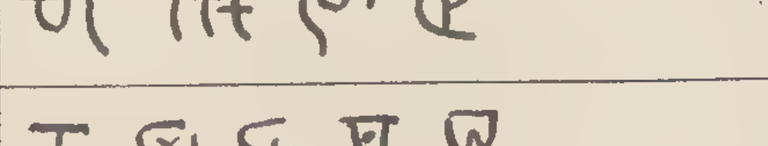
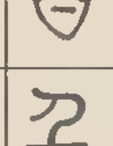
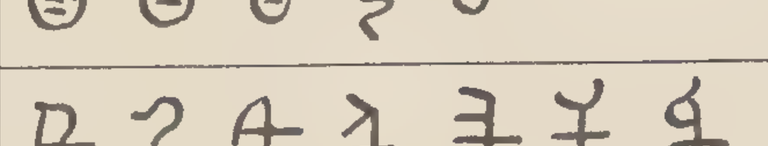
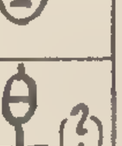
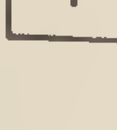
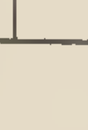
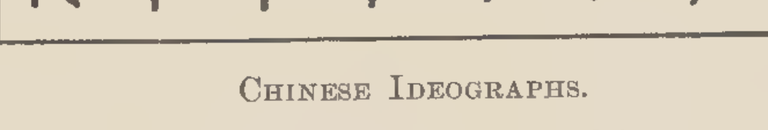
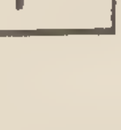
	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms	Probable Original.	Remarks.
379	Obstructed growth, *wö.*						Tree with top cut off. Obsolete form related to No. 380.
380	*Not, *pu.*						Derived from No. 379, which suggests negation.
381	Refuse, not, *fou.*						No. 380 intensified by adding "mouth." Wên-li or literary form of No. 380.
382	Have not, *mu.*					(?)	"The end" < "none" < "no more" < "have not." Also means "drown."
383	†Do not, *wu.*						Derived from "woman" (No. 24).
384	No, *wu.*						Shuo Wên considers this to be an ancient flag with three pennants used for signalling "no."
385	Unyielding not, *fu.*						Something tied with cords. Shuo Wên: "Unyielding. From 'thongs' [No. 197] contracted."
386	Opposed, not, *fei.*						Things (bows?) back to back, hence "opposed."
387	Not yet, *wei.*						Shuo Wên: "Tree in full ceaf and branch." Significance not clear.
388	Without do not, , *mo.*						"Sun" obscured by "leaves" < shady < dark < invisible < without.
389	‡None, minus, *wu.*						Shuo Wên: "Lost."

CHINESE IDEOGRAPHS.

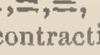
*The Chinese, following Shuo Wên, consider this to be inverted 至 *chïh*, "at," which they interpret as a bird flying to earth. This is far-fetched, and in fact No. 380 is *not* the inversion of the character for "at." I prefer to consider it as derived from No. 379, an ancient sign now discarded.

†Shuo Wên: "Stop. Figure of woman with line across it as if prohibiting illicit conduct."

‡A very obscure symbol. Chinese scholars have made many conjectures, but none satisfactory. I venture an additional guess, to wit, that we must look to No. 207 for the key. The upper part of this (No. 389) exactly corresponds to the chariot-shaft and yokes of No. 207. May it not be a span of horses separated from the cart? Hence "lacking" "without." To this the signs "lost" and "trees" have been added.

	Meaning and Sound.	Modern Form.	Radical.	Seal Form, A. D. 100.	Older Forms.	Probable Original.	Remarks.
390	One, *i.*						One line, or one weapon.
391	Two, *êr.*						Two lines, or two weapons.
392	Three, *san.*						Three lines.
393	Four, *si.*						Four lines, gradually connected in cursory style.
394	Five, *wu.*						Five lines, variously indicated.
395	*Six, *liu.*						Probably six lines united.
396	*Seven, *ch'i.*						Probably seven lines united.
397	*Eight, *pa.*						Eight lines united.
398	Nine, *kiu.*						Probably nine lines united.
399	†Ten, *shih.*						Two contracted signs for *five* united.
400	Twenty, *nien.*						Two tens.
401	Thirty, *shih, so.*						Three tens.
402	Hundred, many, *pei.*						Resembles signs for "head" and "nose." Significance disputed.
403	Thousand, *ch'ien.*						Possibly "hundred-tens" (origin obscure).

CHINESE IDEOGRAPHS.

*The respective signs belong to a distinct system of numerals still used for commercial purposes, which combines figures above five. The vertical line is a contraction of  "five" to which "one," "two" and "three" are added to indicate "six," "seven" and "eight." The regular system combines after "ten."

†This sign is undoubtedly two fives contracted. Originally or some like form, as in the Roman numeral X which is a duplicated V.

VALUES OF LATIN LETTERS IN THE SYSTEM OF ROMANIZED CHINESE USED IN THIS TREATISE, BEING THAT KNOWN AS WADE'S SYSTEM WITH SLIGHT MODIFICATIONS.

a, before ng or final, like "a" in "ball."
an, as in "pan," the vowel tending toward Italian "a."
ai, as long "i" in "like."
ao, as "ow" in "cow."
ê, an obscure sound resembling ŭ.
en, as in "then," tending toward "an."
ĕ, short "e" (not used by Wade).
ei, long "a" (ā) resolving into ē.
i, as ē when final, or ĭ when followed by "n" or "ng."
ih, as ĭ.
ï, an obscure vowel like "e" in "able." (Note used by Wade.)
ia, as "ya" with broad sound of "a."
iao, as "yow."
ie, semi-diphthong with the "e" slightly audible like ē-ĕ.
iu, like "ew" in "few."
o, ō followed by slight breathing like "ō-eh."
ou, ō resolving into ū.
ö, like German ö. (Not used by Wade.)
u, like "oo" in "fool," or like the word "woo."
ü, approximate French sound of "u."
un, like "wen."
ua, " "wa" in "water."
uai, " "wi" in "wise."
ui, " the word "we."
uo, " "woa" in the exclamation "whoa" (hwoa).
uei, " "way."
yu, " the word "you."
ch, " English "j" or soft "g."
ch', " " "ch."
hsi, " "hyee" or "see" (two classes of sounds not distinguished by Wade).
j, " French "j" with trace of "r."
p, nearly like "b."
p', like "p."
t, nearly like "d."
t', like "t."

II. NOTES UPON THE "SHUO WÊN."

As already stated, this great work was published about 120 A. D., and has been repeatedly reëdited by later scholars, preserving, however, what purports to be the original text. This dictionary, being etymological in aim, gives the author's opinion as to the primitive meaning of a word, often with a surmise as to its derivation, and occasionally a suggestion as to pronunciation. In its present form this lexicon defines some ten thousand symbols based upon five hundred and forty[25] "classifiers."

By reference to the appended list of these so-called "classifiers," several peculiarities will be noticed. In the first place they seem to have been selected upon no logical plan, and are entirely too numerous. This latter fault in the system soon manifested itself, for subsequent lexicographers successively reduced the number until the reign of Kanghsi, when the greatest of all Chinese dictionaries appeared under the royal patronage, and classified some 45,000 symbols under 214 determinatives (which are usually called "Radicals"). Of these, 206 were retained out of the original 540, and eight others were added, viz., 8th (亠), 56th (弋), 69th (斤), 71st (元), 88th (父), 90th (爿), 138th (艮), 186th (香).

Secondly they fail to include as classifiers certain ancient symbols as 父, 斤, 艮, and 爿, which found early use in composition. These four have since been recognized as sufficiently important to be used as radicals. The same cannot be claimed for the other five new radicals, for the small groups under each could easily have been distributed among the already recognized classes, *e. g.*, 亠 under 人 or 亠 where most of its class naturally belong; 弋 under 戈; 元 under 几, or 儿.

The "Shuo Wên" recognizes six classes or kinds of symbols, defined as follows:

象形, pictographs, as 木 "tree," ⊙ "sun."

指事, indicators, as 𠫓 "earth piled up," "high."

會意, composites, as 彝 "sacrificial vase."

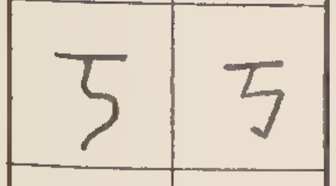
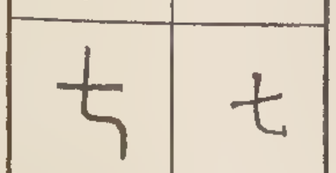
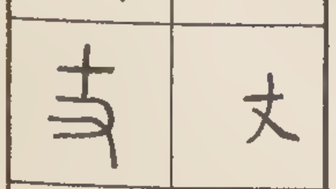
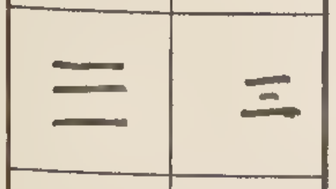
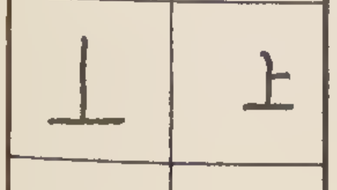
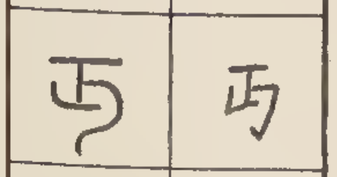
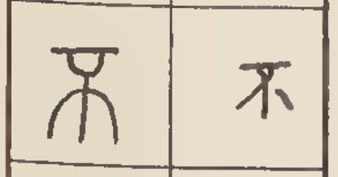
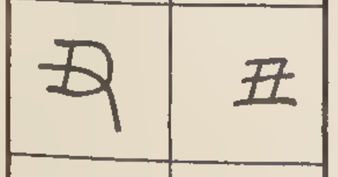
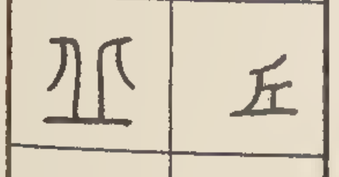
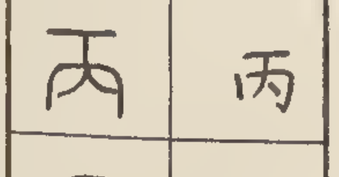
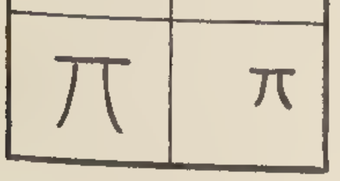
轉註, inversions, as 𠫔 and 𠬜, "son" and "unfilial."

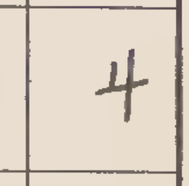
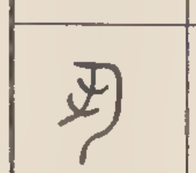
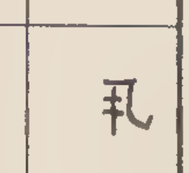
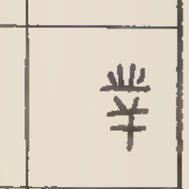
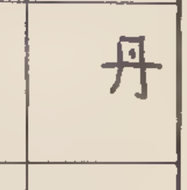
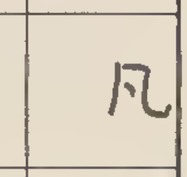
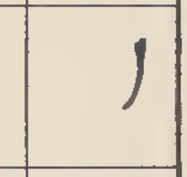
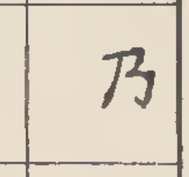
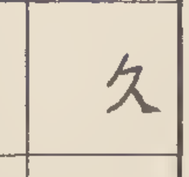
形聲, phonetic signs, as 花 "flower" (化 being merely phonetic).

假借, substitutes (metaphors), as 父 (又) "father" ("hand" holding "rod").

While representative symbols may sometimes apply to more than one class, yet the conception is on the whole quite happy. The definitions and derivations in the Shuo Wên do not always appeal to the student as reasonable, and suggest, what is probably the truth, that many of them are mere guesses on the part of the author. It is possible, however, that the author had access to data and sources of information now lost, and therefore may be right in some cases where his opinion would

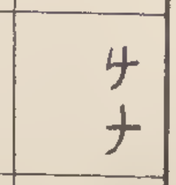
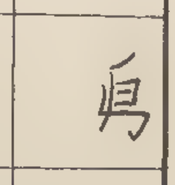
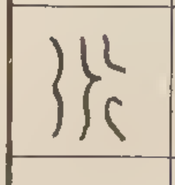
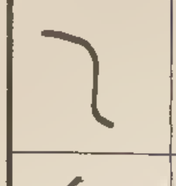
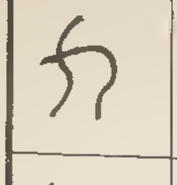
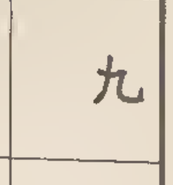
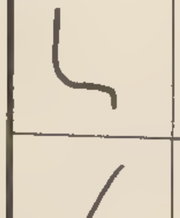
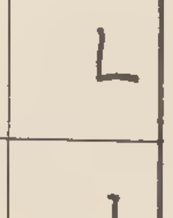
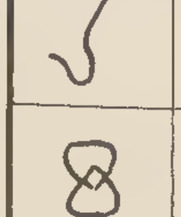
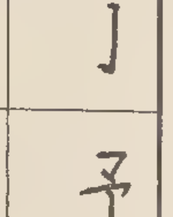
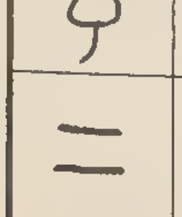
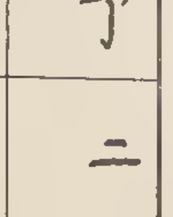
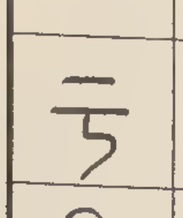
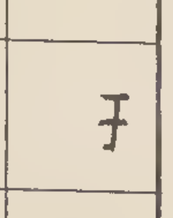
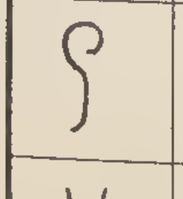
[25] The number of these "classifiers" ranges from 534 to 544, according to the method of computation.

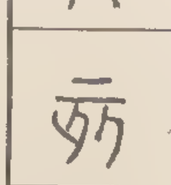
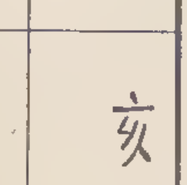
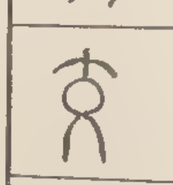
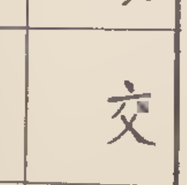
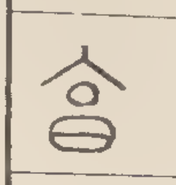
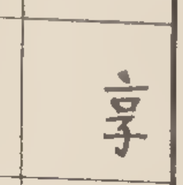
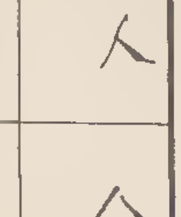
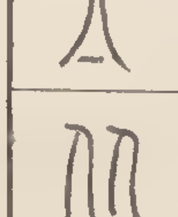
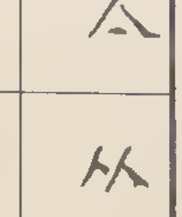
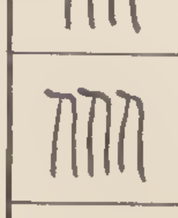
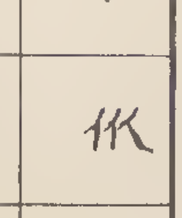
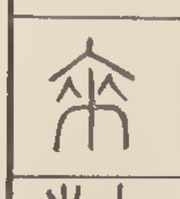
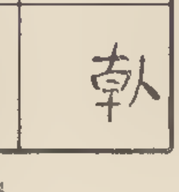
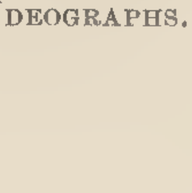
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		One, *i.*	**1st Radical.** See No. 390.
		Undulating air, *k'ao.*	See No. 139.
		Nail, sting? *ting.*	See No. 168.
		Seven, *ch'i.*	See No. 396.
		Ten-feet, *chang.*	Ten *hands.*
		Three, *san.*	See No. 392.
		Above, *shang.*	See No. 287.
		Concealed, *mien.*	
		Not, *pu.*	See No. 380.
		Horary sign, 1–3 A. M., *ch'ou.*	
		Knoll, *k'iu.*	See No. 94.
		South the source of fire, *ping.*	
		A sacrifice, *tsu, ch'ie.*	Original form of No. 356, but now a conjunction *ch'ie.*
		Foundations, *ki.*	

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Staff, *kun.*	**2d Radical.**
		Twist, *k'iu.*	See No. 292.
		Jungle, *kiai.*	Old synonym of No. 112.
		Grasp, *ki.*	
		Luxuriant, *cho.*	
		Lamp-flame, dot, *chu.*	**3d Radical.**
		Cinnabar, *tan.*	
		Pellet, pill, *wan.*	
		Bending to the right, *p'ie.*	**4th Radical.**
		But, rather, *nai.*	
		Following, enduring, *kiu.*	
		To issue, of, *chih.*	See No. 108.
		To heap up, *tui.*	Related to No. 193.
		Bowing, *i.*	

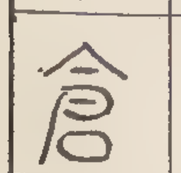
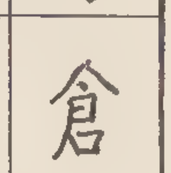
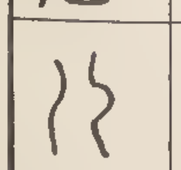
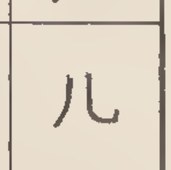
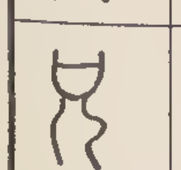
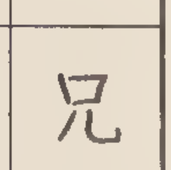
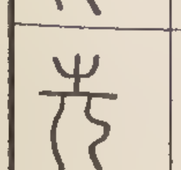
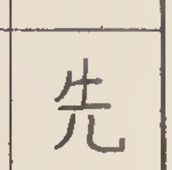
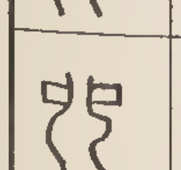
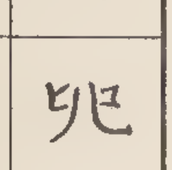
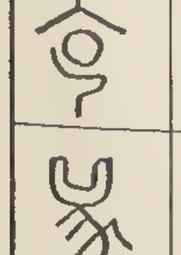
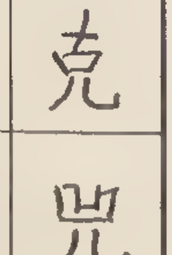
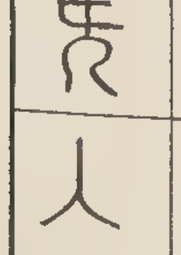
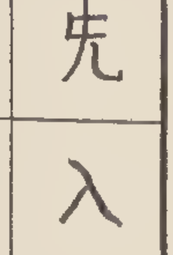
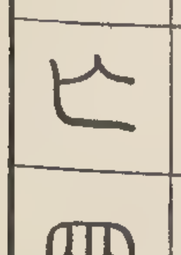
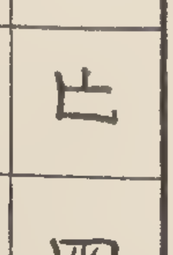
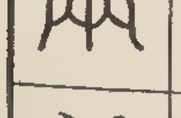
CHINESE IDEOGRAPHS.

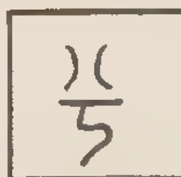
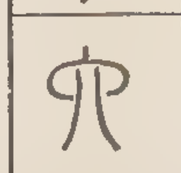
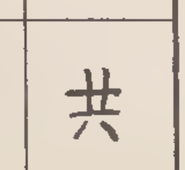
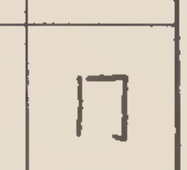
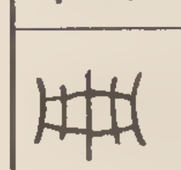
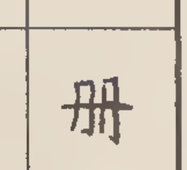
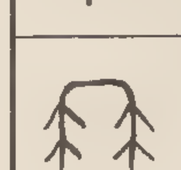
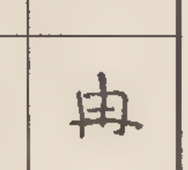
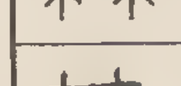
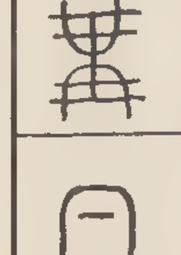
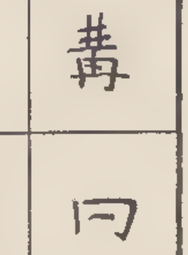
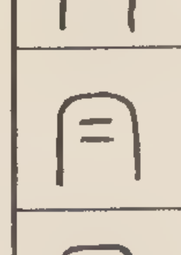
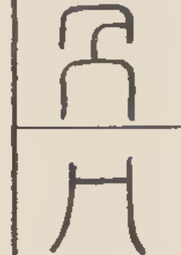
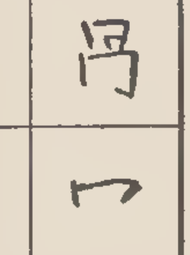
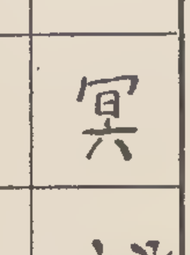
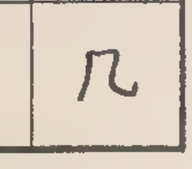
[NOTE. — The numbers in this series (Pl. XXX—XLIX inc.) refer to the numbers of the ideographs in Plates I–XXIX.

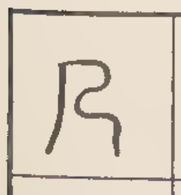
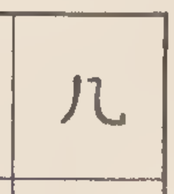
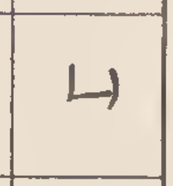
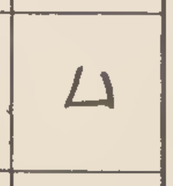
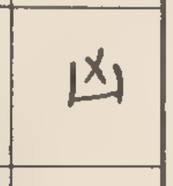
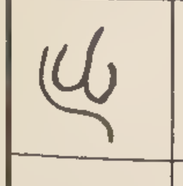
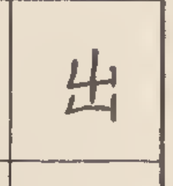
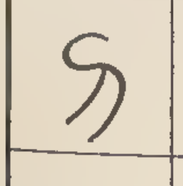
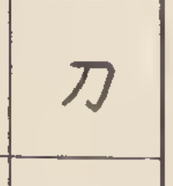
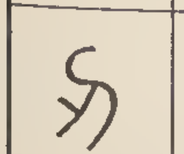
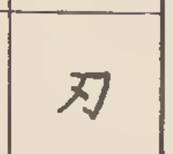
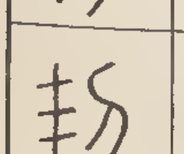
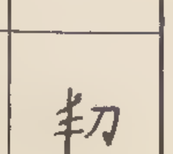
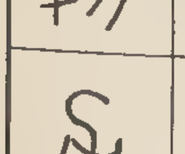
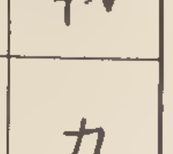
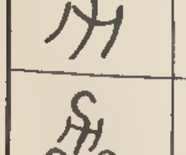
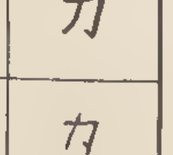
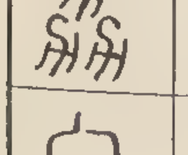
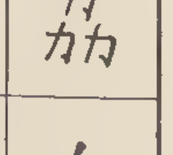
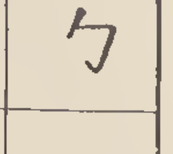
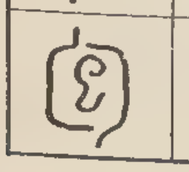
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Bending to the left, *fu.*	
		Left hand, *tso.*	See under 48th Radical. See also No. 67.
		To turn back, *i.*	See No. 268.
		Diverging stream, *p'ai.*	See No. 264.
		Crooked, *i.*	**5th Radical.**
		Nine, *kiu.*	See No. 398.
		Bird of unknown sort, *ya.*	
		Secluded, *yin.*	
		Hook, *k üe.*	**6th Radical.** See No. 192.
		I, me, *yü.*	
		Two, *Er.*	**7th Radical.** See No. 391.
		Stratum of cloud, at, *yü.*	
		Mist, cloud, *yün.*	*Cf.* No. 90.
		Well, *ching.*	See No. 152.

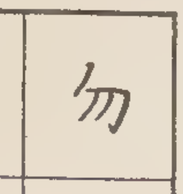
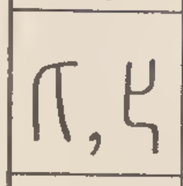
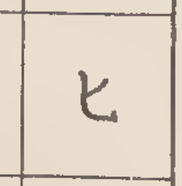
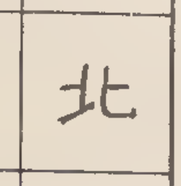
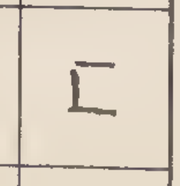
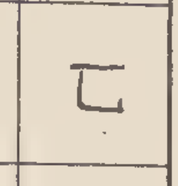
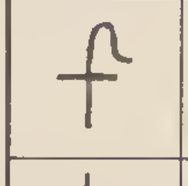
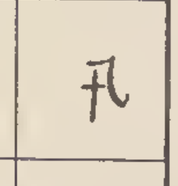
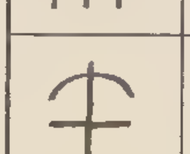
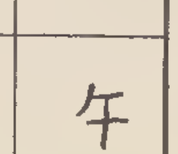
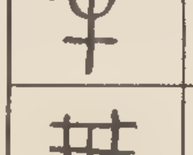
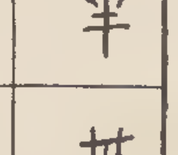
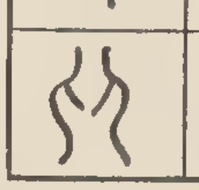
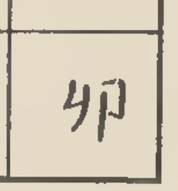
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Hunch-back, ugly, *wö.*	
		Neck, strong, *kang.*	人(亻), **8th Radical** is not a Shuo Wên classifier.
		Horary sign, 9–11 A. M., *hai.*	
		Blend, *kiao.*	See No. 278.
		Armpits, include, also, *i.*	
		Sacrificial jar, enjoy blessings, *hêng, hsiang.*	See Nos. 358, 359.
		Capital City, *king.*	See No. 251.
		Granary, *lin.*	Synonym of No. 187.
		Man (generic), *jên, yin.*	**9th Radical.** See No. 22.
		To assemble, *chi.*	
		To follow, *ts'ung.*	See No. 314.
		A crowd, *chung.*	See No. 70.
		Come, *lai.*	
		Dawn, *kan.*	

CHINESE IDEOGRAPHS.

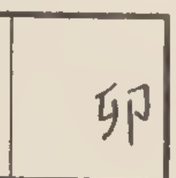
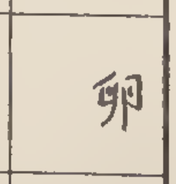
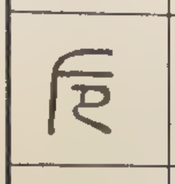
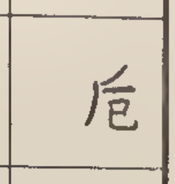
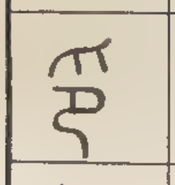
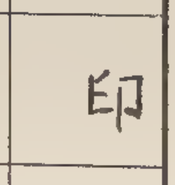
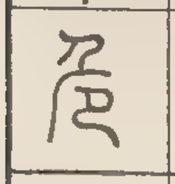
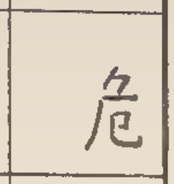
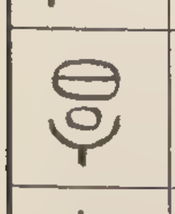
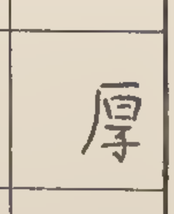
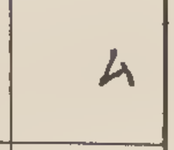
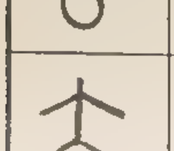
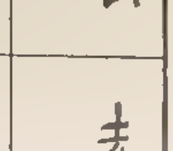
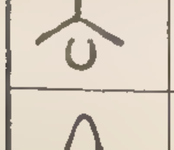
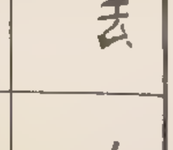
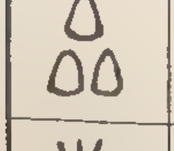
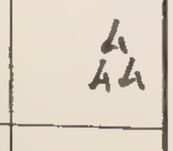
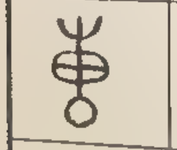
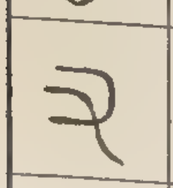
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Flowers, glory, *hua.*	Old variant of No. 106.
		Granary, *ts'ang.*	See No. 187.
		man, *jên, yin.*	**10th Radical.** Variant of No. 22.
		Elder brother, *hsiung.*	
		Precede, *hsien.*	
		Obscure, *ku.*	
		Able, conquer, *k'ê.*	
		Rhinoceros, *hsi.*	See No. 17.
		Hare, *t'u.*	Rude picture of the animal.
		Hairpin, clasp, *tsan.*	
		Enter, inside, *ju, yü.*	**11th Radical.**
		Hidden, lost, *wang.*	
		Two, *liang.*	See No. 295.
		Cut, eight, *pa.*	**12th Radical.** See No. 397.

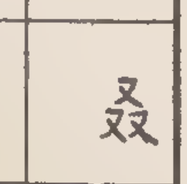
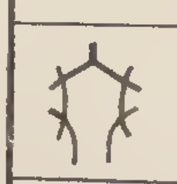
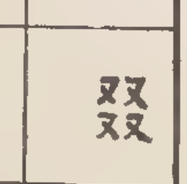
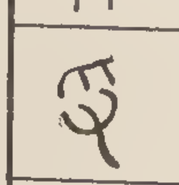
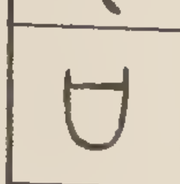
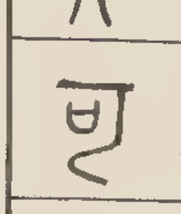
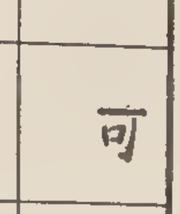
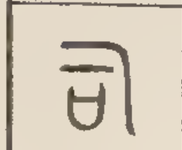
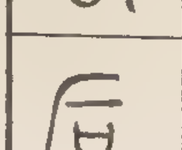
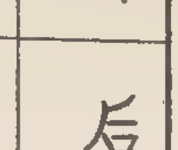
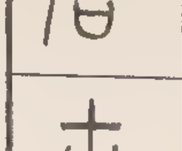
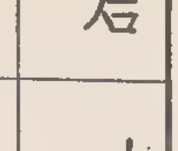
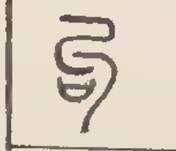
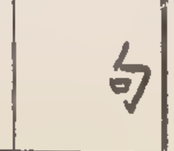
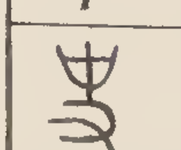
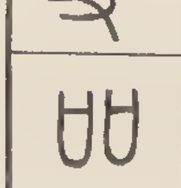
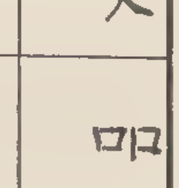
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		An interjection, *hsi.*	
		Six, *liu.*	See No. 395.
		Together, all, *kung.*	See No. 294.
		Frontier, desert, *kiung.*	**13th Radical.** Variant of No. 228.
		List, record, *ts'ê.*	See No. 247.
		Delicate, fine, *jan.*	Possibly related to No. 35.
		Millions, *kou.*	Said to depict the small rafters of a roof.
		Cap, *mao.*	Variant of No. 167.
		Cap, *mao.*	See No. 167.
		To flay, *kua.*	
		Curtain, table cover, *mi.*	**14th Radical.** See No. 176.
		Shade, dark, *ming.*	
		Ice, *ping.*	**15th Radical.** See No. 86.
		Small table, *ki.*	**16th Radical.** See No. 181.

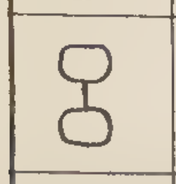
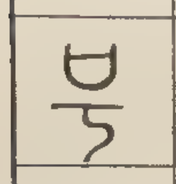
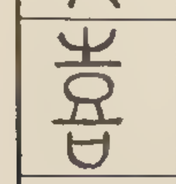
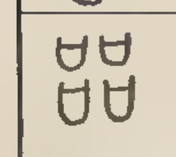
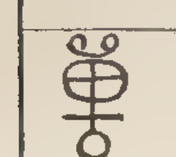
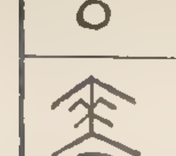
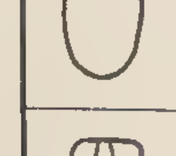
Shuo Wên, classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Short feathers, *shu.*	Component part of Nos. 12 and 20.
		To gape, *k'an.*	**17th Radical.** See No. 47.
		Willow basket, *k'ü.*	See No. 159.
		Unlucky, bad, *hsiung.*	
		A sort of utensil, *ts'u.*	Obsolete, exact form of vessel now unknown.
		To issue, *ch'u.*	See No. 107.
		Knife, *tao.*	**18th Radical.** See No. 164.
		Cutting-edge, *jên, yin.*	The small stroke indicates the knife-edge.
		To notch a stick, *k'i.*	A "notched stick" and "knife."
		Tendon, strength, *li.*	**19th Radical.** See No. 48.
		United strength, concord, *hsie.*	Obsolete.
		Wrap. *pao.*	See No. 327.
		To dip with a ladle, *cho, shuo.*	
		To enfold, *p to.*	See No. 328.

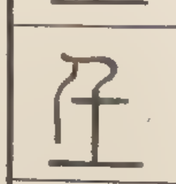
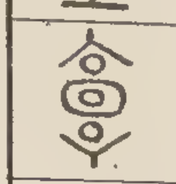
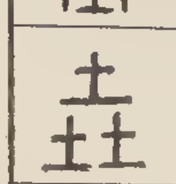
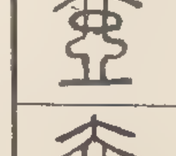
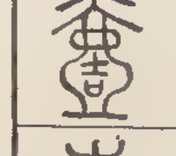
Shuo Wên, classifier.	Modern Form.	Meaning and Sound.	Remarks.
		No, not, *wu.*	See No. 384.
		Spoon, ladle, *pi.*	**21st Radical.** See No. 161.
		Back to back, *pei, po.*	Now used only for "north." Adopted from coincidence of sound.
		Receptacle, *fang.*	**22d Radical.** See No. 182.
		Covered receptacle, coffer, *hsi.*	**23d Radical.** Allied to No. 182.
		Ten, *shih.*	**24th Radical.** See No. 399.
		Fleeing, *hsüan.*	
		Thirty, *so, sa.*	See No. 401. Also old form of No. 297.
		Noon, *wu.*	See No. 303.
		Half, *pan.*	See No. 304.
		Winnowing fan, *pan.*	See No. 189.
		To divine, *pu.*	**25th Radical.** See No. 361.
		Seal, knot, *chie.*	**26th Radical.** See No. 209.
		To rule, *k'ing, chi.*	

CHINESE IDEOGRAPHS.

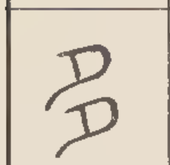
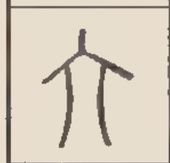
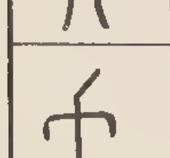
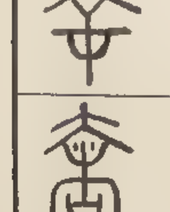
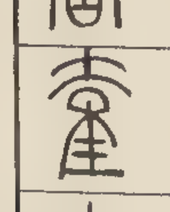
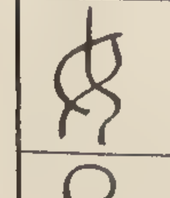
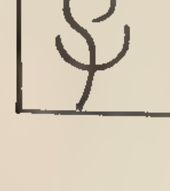
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Horary sign, 5–7 A. M., *mao.*	
		Eggs, *luan.*	See No. 60.
		A round wine-jar, *chih.*	
		Seal, signet, *yin.*	See No. 210.
		Fear, danger, *wei.*	See No. 300.
		Overhanging cliff, *han.*	**27th Radical.** See No. 95.
		Thick, *hou.*	Inversion of No. 359.
		Illicit, *sï.*	**28th Radical.**
		Unfilial, *t'u.*	See No. 310.
		Go, depart, *k'ü.*	
		High, heap, *lei, lui.*	Stones piled up. *Cf.* No. 273.
		Single, only, *chuan.*	
		Right hand, *yu.*	**29th Radical.** See No. 58.
		Hands clasped as in greeting, *kung.*	See also 55th Radical.

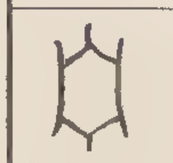
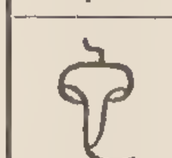
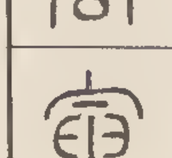
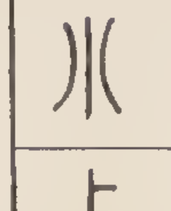
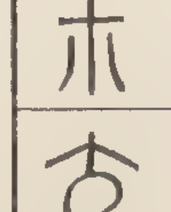
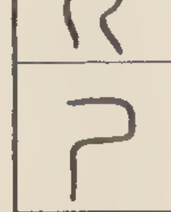
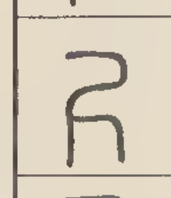
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		To pull, *p'ien.*	Obsolete synonym of No. 219.
		United, *jüe.*	An allied sign of different origin signifies a mythical tree.
		Connected, *cho.*	Obsolete synonym of No. 294.
		To descend, *p'iao.*	
		Mouth, *k'ou.*	**30th Radical.** See No. 34.
		But, only, *chih.*	
		Sign of permission, may, *k'ö.*	
		To control, *sï.*	See No. 242.
		Ruler, *hou.*	See No. 243.
		Ancient, *ku.*	
		Twist, phrase, *kü.*	See No. 326.
		Scribe, *shih.*	See No. 246.
		Cry of terror, *hsüan.*	Two mouths. Obsolete.
		Slow of speech, *na.*	

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	告	To gore, publish, *kao.*	From "ox," and a complex sign now contracted.
	呂	Backbone, *lü.*	See No. 53.
	号	Cry of pain, *hao.*	
	品	Rank, order, *p'in.*	
	哭	To wail, cry, *k'u.*	"Mouth" repeated, and "dog." Originally "howl."
	員	To speak, *yün, yuan.*	
	喜	Happy, glad, *hsi.*	
	器	Many, *chi, ch'i.*	Obsolete. Also old variant of No. 91.
	罟	Beast of burden (sound unknown).	Obsolete. Shuo Wên guesses it to be a horse's head.
	盉	Desire, covet, *shei, sê.*	
	口	Enclosure, *wei.*	**31st Radical.** See No. 142.
	四	Four, *sï.*	See No. 393.
	囟	Top of the head (or) fœtus in womb, *hsin.*	Obsolete.
	囪	Furnace-flue, window, *ch'uang, ts'ung.*	

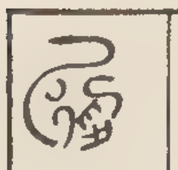
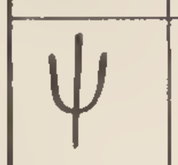
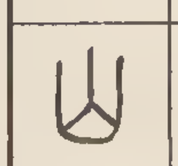
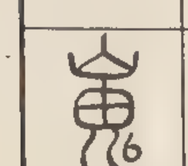
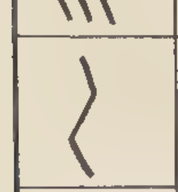
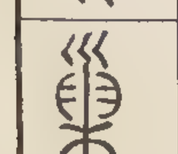
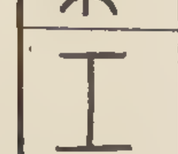
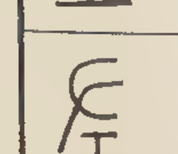
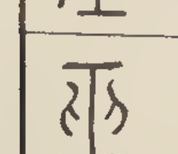
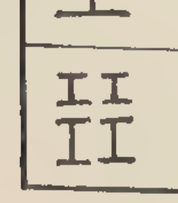
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	囧	Lattice window, *kiung.*	See No. 145.
	土	Earth, clay, *t'u.*	**32d Radical.** See No. 80.
	壬	Complete, full, *t'ing.*	See No. 236.
	垂	Pendant, *ch'ui.*	See No. 272.
	亭	Redoubt, *yung.*	See also under 189th Radical. *Cf.* No. 250.
	堇	Loess earth, *kin.*	From "yellow" and "earth," referring to color of the clay.
	垚	Piled up, high, *yao.*	*Cf.* No. 273.
	士	Officer, scholar, *shih.*	**33d Radical.** See No. 237.
	壬	Great, full, *jên.*	9th of the Ten Stems. *Cf.* No. 236.
	壺	Kettle, *hu.*	Original was a picture of the utensil.
	壹	Single, one, *i.*	Evidently derived from last.
	喜	Joyous, *chü, chu.*	
	夂	Follow, *chih.*	**34th Radical.**
	夂	Weary, *sui, ts'ui.*	**35th Radical.**

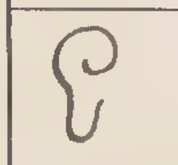
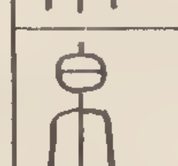
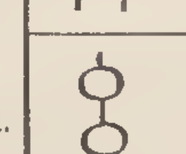
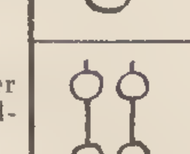
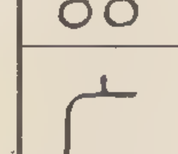
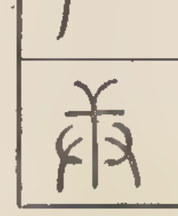
CHINESE IDEOGRAPHS.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	夕	Evening, *hsi.*	**36th Radical.** See No. 131.
	多	Many, *to.*	Origin obscure.
	大	Large, *ta.*	**37th Radical.** See No. 286.
	大	Large, *ta.*	Alternate form of last.
	夫	Master, *fu.*	See No. 244.
	夭	Pleasing, *yao.*	
	夰	Release, *kao, hao.*	
	夲	Go and come, *t'ao.*	
	矢	To kowtow, *nie.*	Man with head inclined.
	奎	Bugbear, bandit, *nie.*	
	奢	Affluent, *shê.*	
	奞	Outspread wings, *sui, hsin.*	
	女	Woman, *nü.*	**38th Radical.** See No. 24.
	子	Male child, *tsï.*	**39th Radical.** See No. 26.

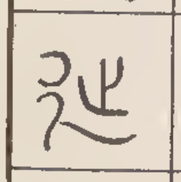
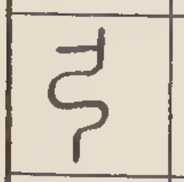
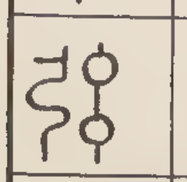
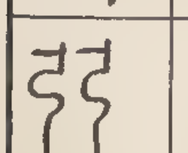
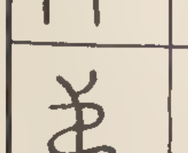
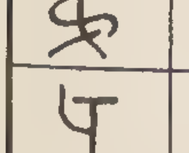
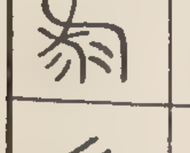
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	孨	Respectful, *chan, chun.*	Obsolete.
	宀	Roof, house, *mien.*	**40th Radical.** See No. 141.
	宁	Store-room, *chü.*	
	它	Cobra, that, another, *t'o.*	Originally a cobra with inflated hood.
	宮	Palace, *kung.*	See No. 144.
	寅	Knee-pan, horary sign, 3–5 P. M., *yin.*	
	寢	Dream, *mêng.*	A contracted form of this is now used.
	寸	Finger-joint, inch, *ts'un.*	**41st Radical.** See No. 43.
	小	Small, *hsiao.*	**42d Radical.** See No. 285.
	尗	Collect, hoard, *shu.*	
	尢	Crooked, deformed, *wang.*	**43d Radical.**
	尸	Corpse, *shih.*	**44th Radical.** See No. 61.
	尺	Foot-measure, *ch'ih.*	
	尾	Tail, end, *wei.*	

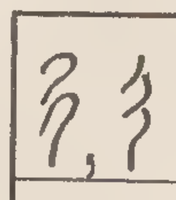
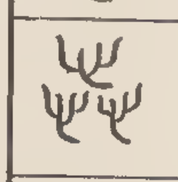
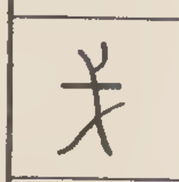
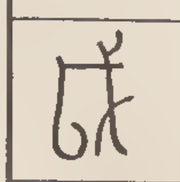
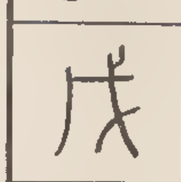
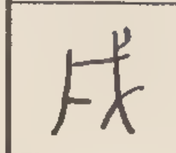
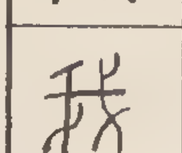
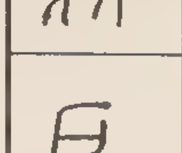
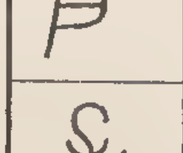
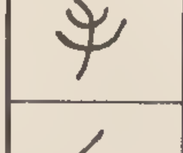
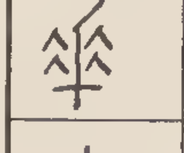
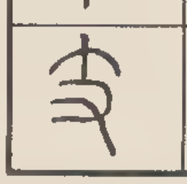
CHINESE IDEOGRAPHS.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	履	Shuo Wên: "That on which the foot rests," *li.*	Shoe > walk > action > conduct.
	屮	Sprout, *ch'ie.*	**45th Radical.** See No. 103.
	山	Hill, mountain, *shan*	**46th Radical.** See No. 93.
	屵	Mountain peak, *yĕ.*	Obsolete except in combination.
	屾	Mountain range, *shĕn.*	Obsolete.
	嵬	High rugged peak, *wei.*	
	川	River, *ch'uan.*	**47th Radical.** See No. 85.
	巛	Brooklet, *kuan.*	Obsolete. *Cf.* No. 85.
	巜	Stream 30 miles long, *kuai.*	Obsolete. *Cf.* No. 85.
	巢	Nest on a tree, *ch'ao, ts'ao.*	Depicts birds in a nest over the sign for tree.
	工	Labor, work, *kung.*	**48th Radical.**
	左	Left-hand, *tso.*	*Cf.* 8th classifier under 4th Radical.
	巫	Divination, magic, *wu.*	*Cf.* No. 369.
	巟	Very skilful, *chan.*	Obsolete.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	己	Self, *ki.*	**49th Radical.**
	已	Horary sign, 9 11 A. M., *si.*	See No. 329.
	巴	Worm, clap hands, *pa.*	See No. 57.
	巾	Head-kerchief, *kin.*	**50th Radical.** See No. 175.
	帀	Pervade, *tsa.*	
	市	Market, *shih.*	See No. 177.
	帛	White silk, *po, pei.*	
	帚	Ragged, *pi.*	Obsolete.
	干	Shield, weapon, *kan.*	**51st Radical.** See No. 216.
	幵	Level, even, *k'ien.*	See No. 283.
	幺	Young, tender, *yao.*	**52d Radical.** See No. 330.
	幺幺	Small, fine, *yu.*	See No. 331.
	广	Shed, cover, *yan, yen.*	**53d Radical.** See No. 143.
	庚	Change, age, *kêng.*	

CHINESE IDEOGRAPHS.

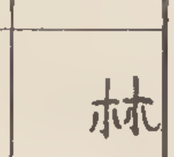
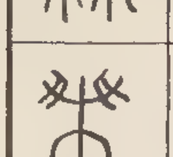
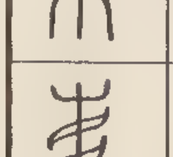
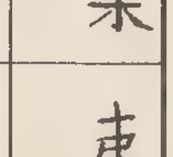
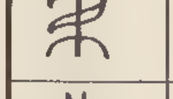
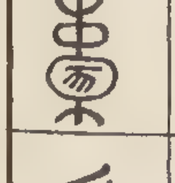
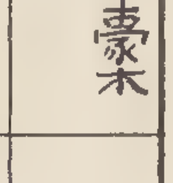
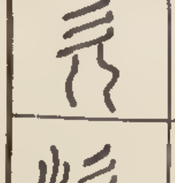
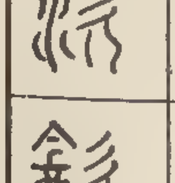
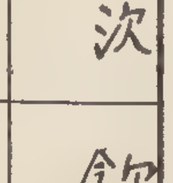
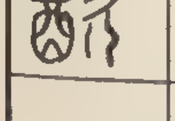
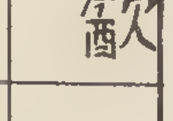
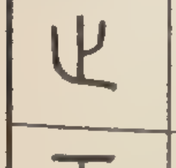
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	鹿	Unicorn, *chai.*	Allied to No. 3.
	夂	To move on, *yin.*	**54th Radical.** See No. 315.
	延	To go steadily, slow, *ch'ien, ch'an.*	
	廾	Fear, excited, *kung.*	**55th Radical.** See also under 29th Radical.
	弋	Lance, *i.*	**56th Radical** is not a Shuo Wên classifier.
	弓	Bow (weapon), *kung.*	**57th Radical.** See No. 211.
	弦	Bow-string, *hsien.*	From "bow" and "silk" contracted.
	马	Twang of a bow, *han.*	Obsolete.
	弱	Strong, *k'iang.*	"Bow" duplicated.
	弟	Younger brother, *ti.*	
	彐	Swine snout, *ki.*	**58th Radical.** *Cf.* No. 18.
	象	Carved wood, *lu.*	Supposed to depict carved lines.
	彡	Stripes, feathers, *shan.*	**59th Radical.**
	文	Writing, sign, *wên.*	Variant of No. 279.

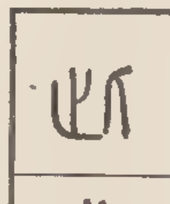
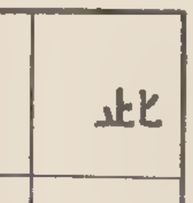
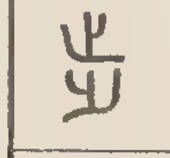
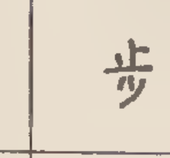
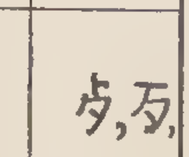
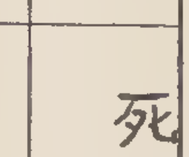
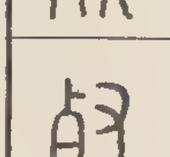
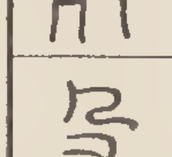
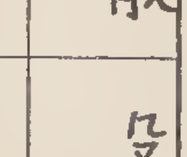
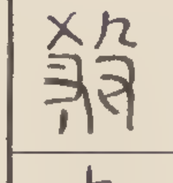
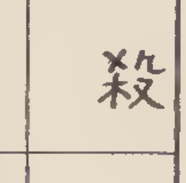
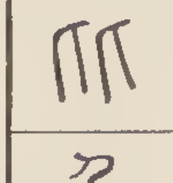
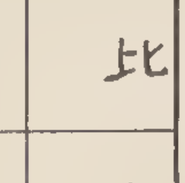
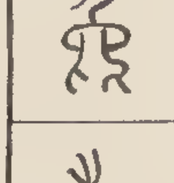
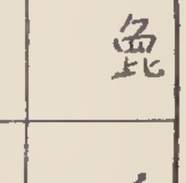
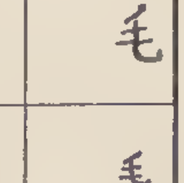
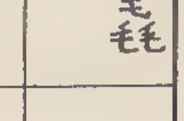
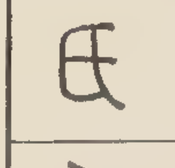
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	彳	Short-step, walk, *ch'ih.*	**60th Radical.** See No. 311.
	心	Heart, *hsin.*	**61st Radical.** See No. 41.
	思	Think, consider, *sï.*	
	忄	Doubtful, *so, jui.*	
	戈	Halberd, *kuo.*	**62d Radical.** See No. 213.
	戉	Battle-axe, *yo, yüe.*	
	戊	Battle-axe, *wu, mou.*	5th of the Ten Stems. Relates to earth. See No. 214.
	戌	Horary sign, 7–9 P. M., *hsü.*	Not same as No. 215.
	我	I, me, *wö.*	See No. 307.
	戶	Window, *hu.*	**63d Radical.** See No. 191.
	手	Hand, *shou.*	**64th Radical.** See No. 36.
	垂	Hand, *shou.*	Obsolete variant of last.
	才	Substance, *ts'ai.*	
	支	Branch, *chih.*	**65th Radical.**

CHINESE IDEOGRAPHS.

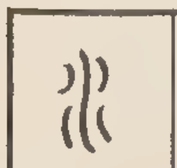
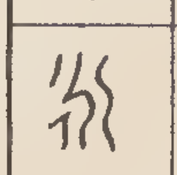
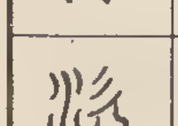
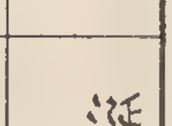
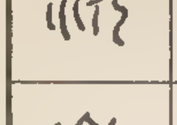
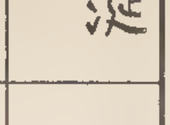
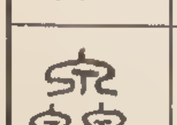
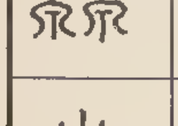
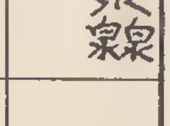
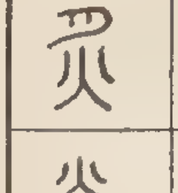
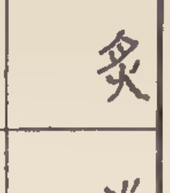
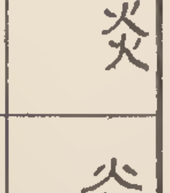
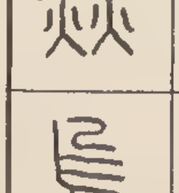
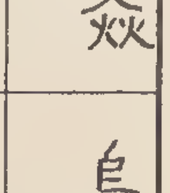
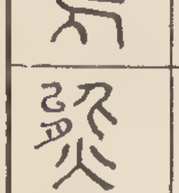
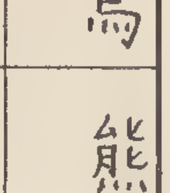
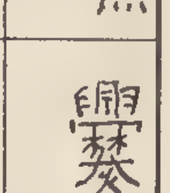
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
攴	攴	Tap, rap, *pu.*	**66th Radical.**
放	放	Release, *fang.*	
教	教	Teach, to cause, *kiao.*	
文	文	Sign, mark, *wên.*	**67th Radical.** See No. 279.
斗	斗	Dipper, peck, *tou.*	**68th Radical.** See No. 160. *Cf.* No. 188.
	斤	Axe, *kin.*	**69th Radical** is not a Shuo Wên classifier.
	方	Square, *fang.*	**70th Radical.** Related to No. 182.
	无	Vacant, *wu.*	**71st Radical** is not a Shuo Wên classifier.
旡	旡	Indigestion, *ki.*	Reverse of 76th Radical, *q. v.*
日	日	Sun, day, *ji, i.*	**72d Radical.** See No. 71.
旦	旦	Sunrise, *tan.*	See No. 74.
㫗	㫗	Decree, *chih.*	See No. 259.
是	是	Just now, this, *shih.*	See No. 302.
朙	明	Bright, clear, *ming.*	See No. 77.

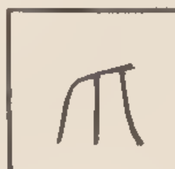
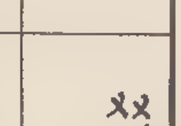
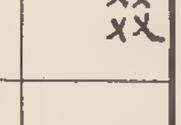
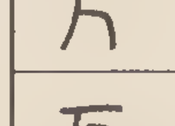
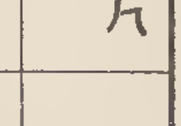
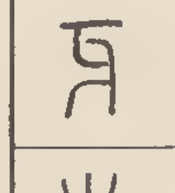
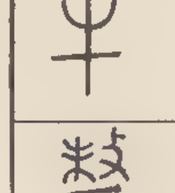
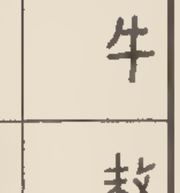
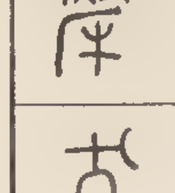
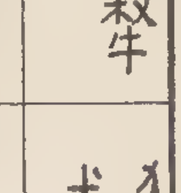
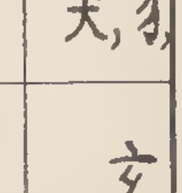
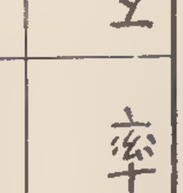
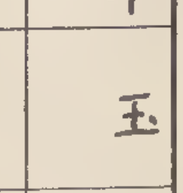
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
易	易	To change, easy, *i.*	
㬎	晨	Dawn, *ch'ên.*	
晶	晶	Quartz crystal, *ching.*	See No. 75.
曰	曰	Speak, *yüe.*	**73d Radical.**
曲	曲	Crooked, bent, *k'ü.*	See No. 309.
會	會	To congregate, *hui.*	
月	月	Moon, month, *yüe.*	**74th Radical.** See No. 72.
有	有	Have, hold, *yu.*	Hand grasping an object.
木	木	Tree, wood, *mu.*	**75th Radical.** See No. 97.
本	本	Root, origin, *pên.*	
未	未	Not yet, horary sign 1–3 P. M., *wei.*	See No. 387.
束	束	Bind, tie, *shu, su.*	
朿	朿	Thorn, *ts'i.*	See No. 125.
東	東	Sunrise, east, *tung.*	See No. 121.

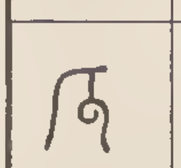
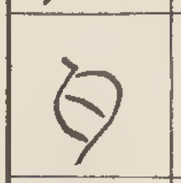
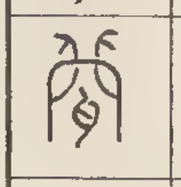
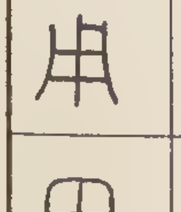
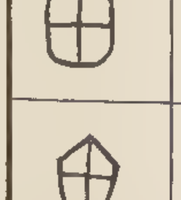
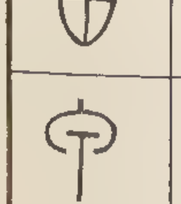
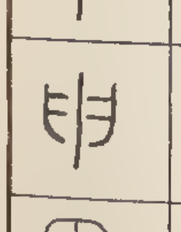
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Grass-husk, *fên.*	See No. 100.
		Thrifty growth, *p'o.*	See No. 101.
		Grove, *lin.*	See No. 98.
		Flowers, *p'i.*	See No. 99.
		Cruel, *kie.*	Possibly "men" impaled on branches of a "tree."
		Pendant fruit, *han.*	Depicts fruit on a tree.
		Pursuit, trade, *yĕ.*	
		Varnish, *ch'i.*	"Tree" and "water," *i. e.*, "tree-sap."
		To bind, *hun, kun.*	Obsolete.
		Yawn, weary, deficient, *k'ien.*	**76th Radical.** Reversed form of 1st classifier under 71st Radical.
		Spittle, *ch'ien, yen.*	Obsolete. See also under 85th Radical.
		Drink, *yin.*	Obsolete.
		Stop, *chih.*	**77th Radical.** See No. 110.
		Exact, *chêng.*	See No. 111.

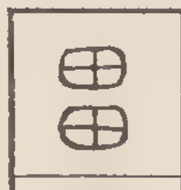
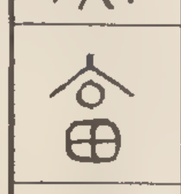
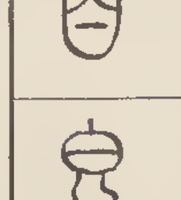
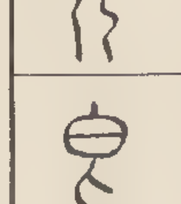
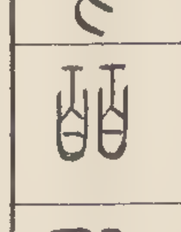
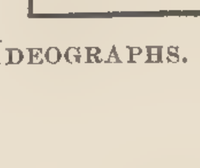
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		This, here, *ts'ï.*	From "man" and "stop."
		Step, *pu.*	See No. 318.
		Bad, *tai.*	**78th Radical.**
		Dead, die, *sï.*	From "man" and "bad."
		To bore a hole, *chan.*	
		A long spear, kill, *shu.*	**79th Radical.** "Man" and "hand" suggesting killing.
		Kill, *sha.*	
		Do not, *wu.*	**80th Radical.** See No. 383.
		Equal, *pi.*	**81st Radical.** See No. 282.
		Animal like a hare, *ch'üe.*	Obsolete.
		Hair, *mao.*	See No. 35.
		Fur, *ts'ui.*	Three hairs.
		Clan, family, *shih.*	**83d Radical.**
		Vapor, *k'i.*	**84th Radical.** See No. 136.

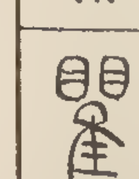
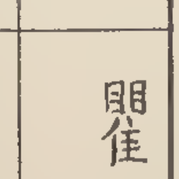
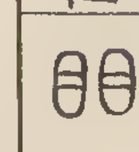
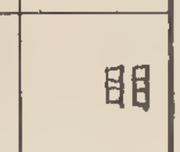
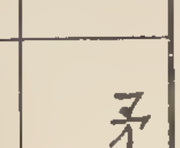
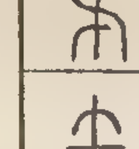
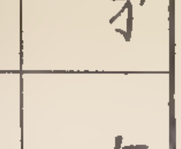
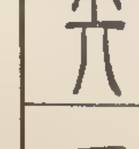
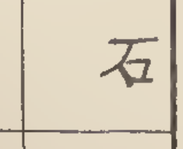
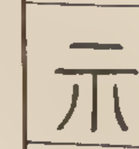
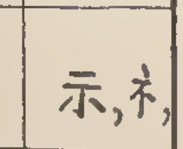
CHINESE IDEOGRAPHS.

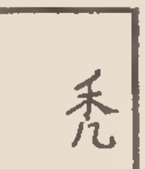
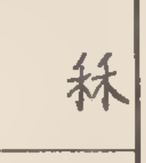
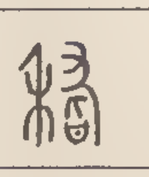
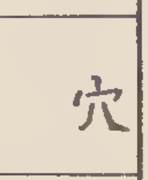
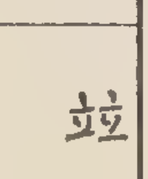
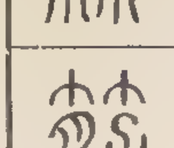
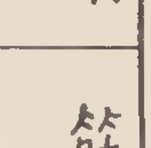
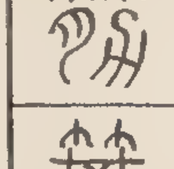
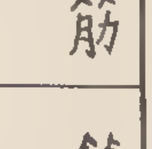
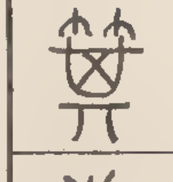
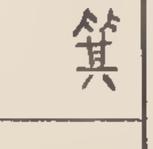
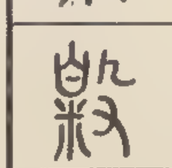
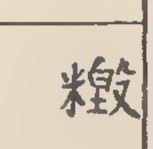
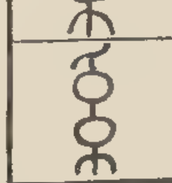
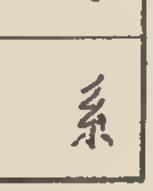
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Water, *shui.*	**85th Radical.** See No. 84.
		Perpetual, *yung.*	See No. 265.
		Rivers, *ch'ui.*	Obsolete plural.
		Spittle, *ch'ien, yen.*	See also under 76th radical.
		Water-spring, *ch'üan.*	See No. 87.
		Mingled waters, *hsün, ch'uan.*	Obsolete.
		Fire, *huo.*	**86th Radical.** See No. 81.
		To roast, *chih.*	"Flesh" over "fire."
		Flame, hot, *yen.*	"Fire" duplicated.
		Intense heat, brilliant, *yen.*	"Fire" triplicated.
		Raven, *wu.*	See No. 20.
		The bear, *hsiung.*	
		To cook, stove, *ts'uan,*	Obsolete. See No. 171.
		The swallow, *yen.*	See No. 14.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Claw, talons, *chao.*	**87th Radical.** See No. 44.
		Father, *fu.*	**88th Radical** is not a Shuo Wên classifier.
		To blend, *yao.*	**89th Radical.**
		White cloth, *h.*	Depicts textile fabric. Obsolete.
		Bed, *ch'uang.*	**90th Radical** is not a Shuo Wên classifier.
		Splinter, *p'ien*	**91st Radical.** See No. 341.
		Tooth, *ya.*	**92d Radical.** See No. 51.
		Cow, ox, *niu.*	**93d Radical.** See No. 5.
		The yak, *li.*	
		Dog, *k'üan.*	**94th Radical.** See No. 7.
		Skyblue, dark, *hsüan.*	**95th Radical.**
		Lead, command, *shuai.*	Depicts a banner as sign of rank.
		Jadestone, *yü.*	**96th Radical.** *Cf.* No. 234.
		King, *wang.*	See No. 234.

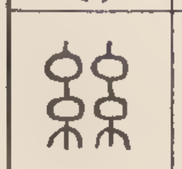
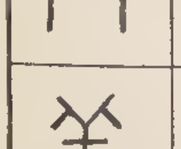
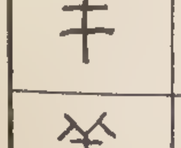
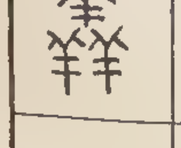
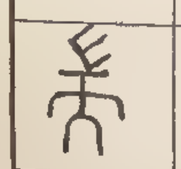
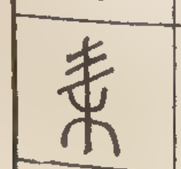
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	玨	Jade ornament, *küe.*	Occurs only in proper names.
	琴	Lute, violin, *k'in.*	See No. 198.
	瓜	Melon, *kua.*	**97th Radical.**
	瓠	Gourd, *hu.*	
	瓦	Tile, *wa.*	**98th Radical.** See No. 196.
	甕	Flexible thongs, *tsun.*	Obsolete.
	甘	Sweet, *kan.*	**99th Radical.** See No. 342.
	生	Produce, *shêng.*	**100th Radical.** See No. 109.
	用	Use, *yung.*	**101st Radical.** See No. 344.
	田	Field, *t'ien.*	**102d Radical.** See No. 184.
	疋	Demon's head, *fu.*	*Cf.* 354.
	甲	Fingernail, *kia.*	See No. 42.
	申	Deity, horary sign, 3–5 P. M., *shĕn.*	See No. 352.
	男	Human male, *nan.*	See No. 23.

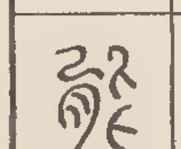
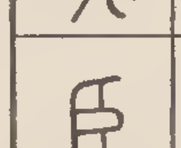
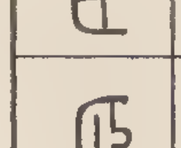
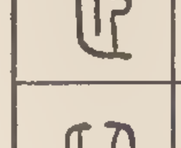
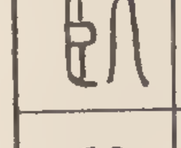
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	畕	Adjacent fields, *kiang.*	Obsolete.
	畎	Weedy land, *chüh.*	Occurs in No. 23.
	異	Strange, *i.*	See No. 345.
	福	Blessed, *fu.*	Allied to No. 358.
	畫	Paint, draw, *hua.*	
	疋	A roll of cloth, *p'i.*	**103d Radical.**
	疒	Sick, *ni.*	**104th Radical.** "Man" on a "bed." *Cf.* No. 154.
	癶	Back to back, opposed, *po.*	**105th Radical.**
	癸	Water soaking into the ground, *kuei.*	10th stem, relating to north and water.
	白	White, *pai.*	**106th Radical.** Depicts white of the eye.
	皃	Form, *mao.*	See No. 46.
	皂	Dark gray, drab, *tsao.*	
	皕	Two hundred, *pi.*	"Hundred" duplicated. Obsolete.
	皮	Rawhide, *p'i.*	**107th Radical.**

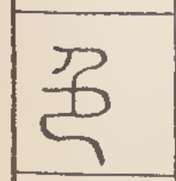
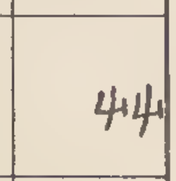
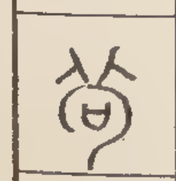
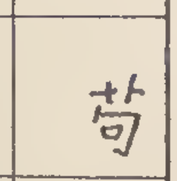
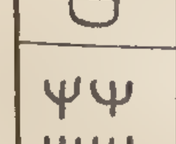
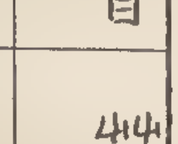
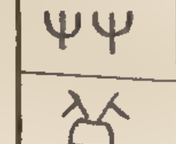
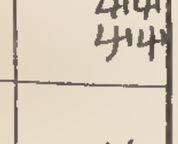
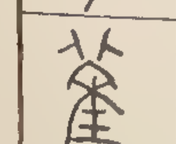
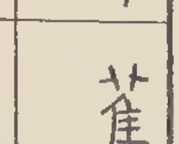
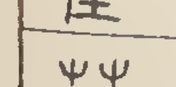
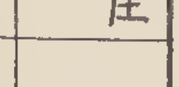
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Dish, *min.*	**108th Radical.** See No. 155.
		Eye, *mu.*	**109th Radical.** See No. 31.
		Eye-brows, *mei.*	See No. 49.
		Shield, *tun, shun.*	See No. 232.
		To look up, *hsie.*	Obsolete.
		Behead (?), *kiao, kao.*	Obsolete.
		Timid, *kii.*	Bird's eyes.
		To look right and left, *kii.*	Two eyes.
		Lance, *mao.*	**110th Radical.** See No. 220.
		Arrow, *shih.*	**111th Radical.** See No. 212.
		Stone, *shih.*	**112th Radical.** See No. 96.
		Heaven's influence, *sï.*	**113th Radical.** See No. 353.
		Foot-print, track, *jou.*	**114th Radical.**
		Growing crops, *hö, huo.*	**115th Radical.** See No. 118.

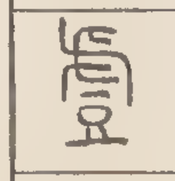
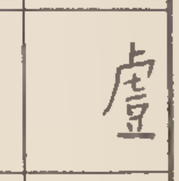
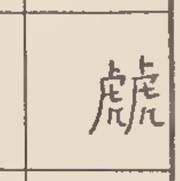
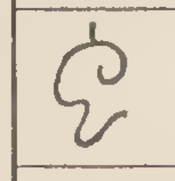
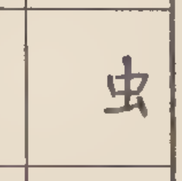
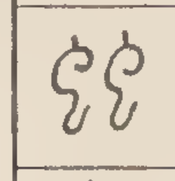
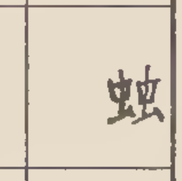
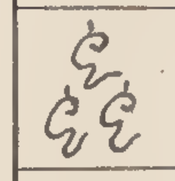
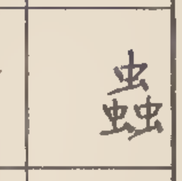
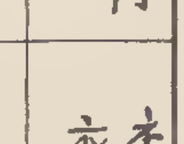
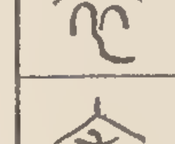
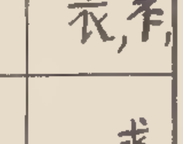
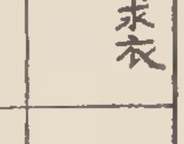
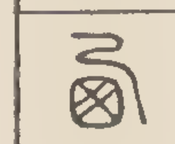
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Bald, bare, *t'u.*	
		Rare, seldom, *li.*	
		Investigate, *ki.*	
		Cave, *hsüe.*	**116th Radical.** See No. 194.
		Set up, stand, *li.*	**117th Radical.** See No. 320.
		Two abreast, *ping.*	See No. 321.
		Crime, misfortune, *k'ien.*	
		Bamboo, *chu.*	**118th Radical.** See No. 117.
		Sinew, *kin.*	
		Winnowing fan, *ki.*	See No. 183.
		Shelled grain, *mi.*	**119th Radical.** See No. 124.
		A grain measure, *hui.*	Obsolete.
		Silk, *mi.*	**120th Radical.** See No. 134.
		Connect, bind, *hsi.*	

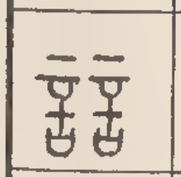
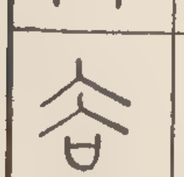
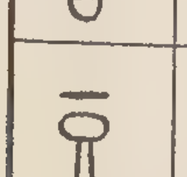
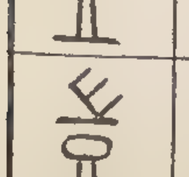
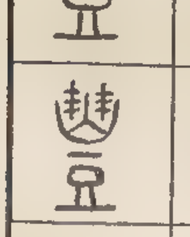
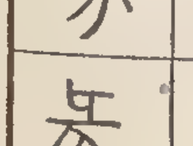
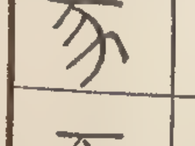
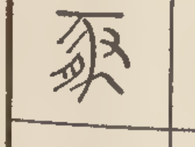
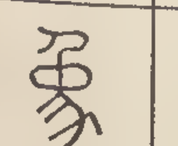
CHINESE IDEOGRAPHS.

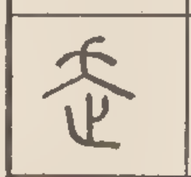
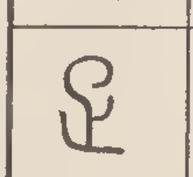
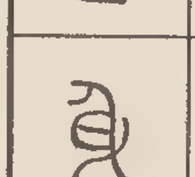
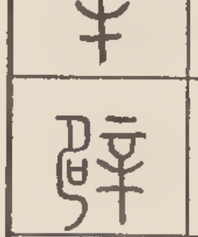
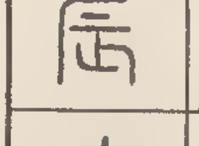
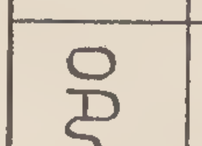
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	素	White silk lace, *su, so.*	*Cf.* No. 134.
	絲	Silk thread, *sï.*	See No. 135.
	缶	Pottery, jar, *fou.*	**121st Radical.** See No. 158.
	网	Net, *wang.*	**122d Radical.** See No. 165.
	羊	Sheep, goat, *yang.*	**123d Radical.** See No. 6.
	羴	Odor of goats, rancid, *shan.*	A flock of goats.
	羽	Long feathers, *yü.*	**124th Radical.** See No. 45.
	習	Constant flight, to practice, *hsi.*	
	老	Old, venerable, *lao.*	**125th Radical.**
	而	Whiskers, *êr.*	(Now a conjunction.) See No. 38.
	耑	Spring up, cause, *tuan.*	Sprout with roots. (Not from last.)
	耒	Plow, *lui, lei.*	**127th Radical.**
	耳	Ear, *êr.*	**128th Radical.** See No. 32.
	聿	Stylus, pen, *yü.*	**129th Radical.** See No. 202.

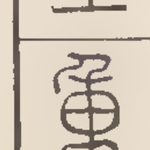
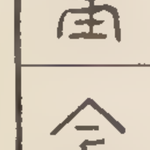
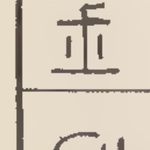
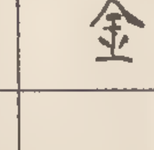
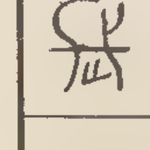
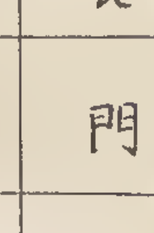
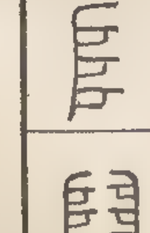
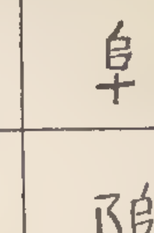
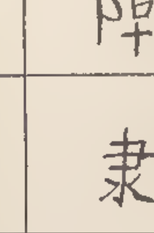
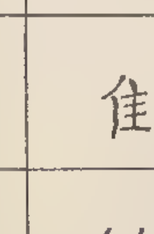
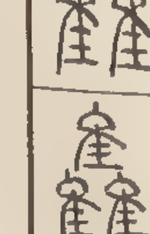
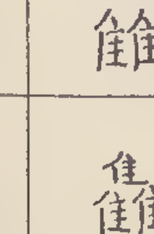
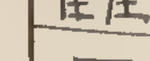
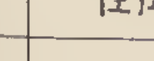
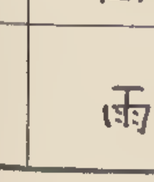
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	聿	Bamboo brush, *nie.*	Obsolete.
	月,肉	Flesh, *jou.*	**130th Radical.** See No. 54.
	能	Natural ability, able, *nêng.*	Original depicts some strong beast like the bear.
	臣	Prime Minister, *ch'ĕn.*	**131st Radical.** See No. 239.
	臣	Chin, *i.*	
	臥	Recline, rest, *wŏ, ngö.*	
	臤	Moral, worthy, *hsien.*	
	自	Nose, self, *tsï.*	**132d Radical.** See No. 269.
	百	Head, *shou.*	Obsolete form of No. 29.
	至	Unto, towards, *chih.*	**133d Radical.**
	臼	Mortar, *kiu.*	**134th Radical.** See No. 200.
	舀	Kiln, *kü.*	See No. 201.
	舁	Offer, lift up, *yü.*	Perhaps related to No. 346.
	舌	Tongue, *shê.*	**135th Radical.** See No. 56.

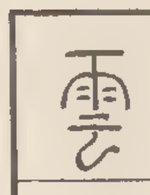
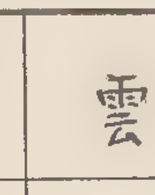
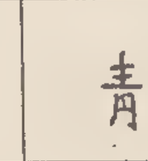
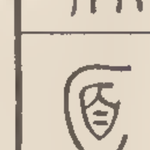
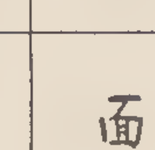
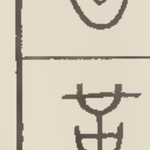
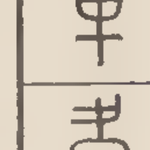
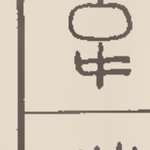
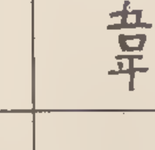
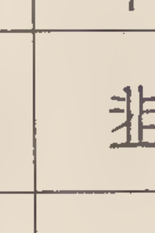
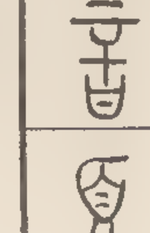
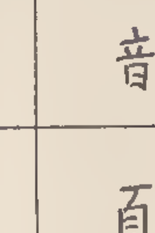
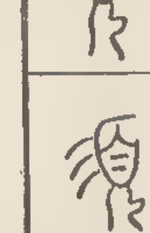
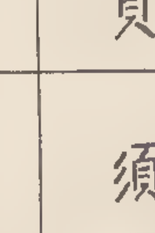
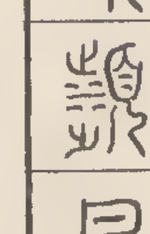
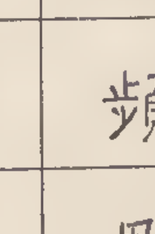
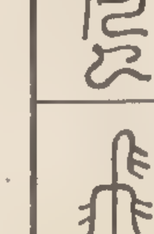
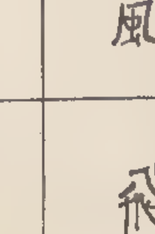
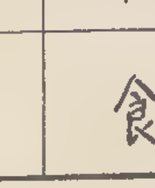
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Opposed, perverse, *ch'uan.*	**136th Radical.**
		Tangled brush, thicket, *shun.*	
		Boat, ship, *chou.*	**137th Radical.** See No. 170.
		Root, *kên.*	**138th Radical** is not a Shuo Wên classifier.
		Color, lust, *shei, shê.*	**139th Radical.**
		Grass, plants, leaves, *ts'ao.*	**140th Radical.** See No. 104.
		Illicit, *kou.*	
		Clover, *mu.*	
		Herbs (generic), *mang.*	Obsolete variant of No. 115.
		Goat's horns, *huan.*	Origin obscure.
		Flowers, glory, *hua.*	See No. 106.
		Horned owl, *huan.*	"Horns" (not "grass") over "bird."
		Sprouts, *ju.*	
		Tiger, *hu.*	**141st Radical.** Variant of No. 2.

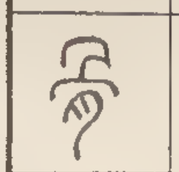
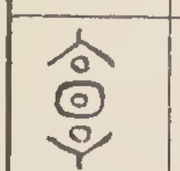
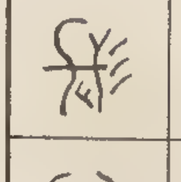
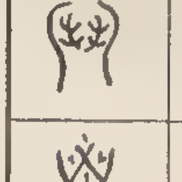
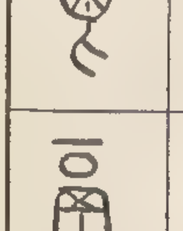
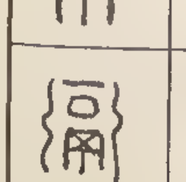
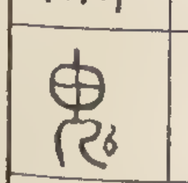
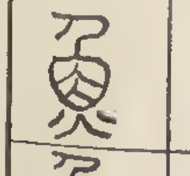
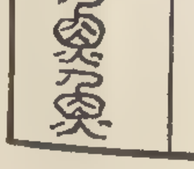
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Tiger, *hu.*	Same as last. See No. 2.
		Sacrificial vase, *hsi.*	Obsolete.
		Tiger rampant, *yen, hsien.*	Obsolete.
		Worm, insect, *ch'ung.*	**142d Radical.** See No. 11.
		Reptiles, *k'un.*	"Worm" duplicated, suggesting a *larger* class of animals.
		Insects (generic), *ch'ung.*	"Worm" or "insect" triplicated, suggesting large numbers.
		Blood, *hsüe.*	**143d Radical.** See No. 55.
		To go, step, *hsing.*	**144th Radical.** See No.317.
		Cloak, *i.*	**145th Radical.** See No. 166.
		Skin garments, *k'iu.*	
		A cover, lid, *hsia.*	**146th Radical.**
		West, *hsi.*	See No. 122.
		See, look, *kien.*	**147th Radical.** See No. 267.
		Look, *yao.*	Obsolete.

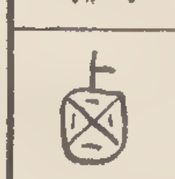
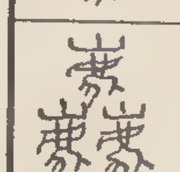
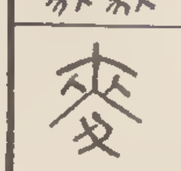
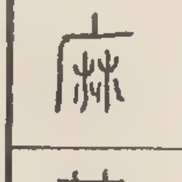
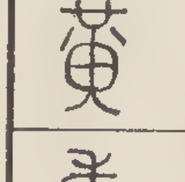
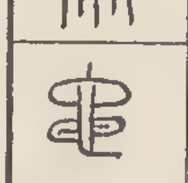
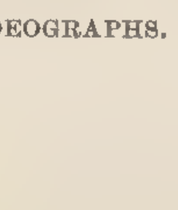
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	角	Horn, *kiao, küe.*	**148th Radical.** See No. 50.
	言	Speech, *yen.*	**149th Radical.** See No. 276.
	詰	Dispute, *king.*	"Words" *vs.* "Words."
	谷	Valley, ravine, *ku.*	**150th Radical.**
	合	Laughter, *küe, kiu.*	Obsolete.
	豆	Stemmed dish, *tou.*	**151st Radical.** See No. 156.
	豈	Why, how, *k'i.*	
	豐	Plenty, rich, *fêng.*	See No. 323.
	豕	Pig, *shih.*	**152d Radical.** *Cf.* No 18.
	彖	Pig, *shih.*	Variant of last. See No. 18.
	腞	Pig, pork, *t'un.*	Synonym of last.
	象	Elephant, *hsiang.*	See No. 1.
	豸	Unicorn, *chai.*	**153d Radical.** See No. 16.
	貝	Shell, value, *pei.*	**154th Radical.** See No. 132.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	貫	To string, connect, *kuan.*	Contracted form of No. 336.
	赤	Red, *ch'ih.*	**155th Radical.** "Great" and "fire."
	走	To go, walk, *tsou.*	**156th Radical.** See No. 316.
	足	Foot, *tsu.*	**157th Radical.** See No. 37.
	身	Body, *shĕn.*	**158th Radical.** See No. 28.
	車	Chariot, cart, *ch'ê.*	**159th Radical.** See No. 206.
	辛	Bitter, *hsin.*	**160th Radical.** See No. 343.
	辟	Prince, *pi.*	
	辡	Adversaries in court, debate, *pien, p'ien.*	
	辰	Morning, horary sign, *ch'ĕn.*	**161st Radical.**
	辵,辶	To run, *cho.*	**162d Radical.** See No. 312.
	邑	City, *i.*	**163d Radical.** See No. 249.
	邠	(Meaning and sound unknown.)	Used only in combination.
	酉	Amphora, horary sign, 5–7 P. M., *yu.*	**164th Radical.** See No. 172.

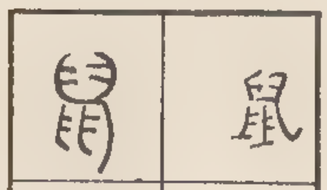
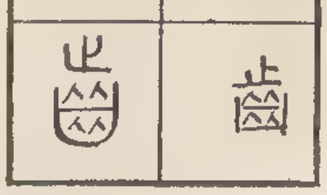
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Old wine, ripe, *ch'iu.*	Derived from last.
		To sort out, *pien.*	**165th Radical.** See No. 348.
		Village, third of a mile, *li.*	**166th Radical.**
		Heavy, *chung.*	
		Metal, *kin.*	**167th Radical.** See No. 82.
		Long, *ch'ang.*	**168th Radical.**
		Door, *mên.*	**169th Radical.** See No. 169.
		Mound, *fou.*	**170th Radical.** See No. 193.
		Depression between mounds, *fou, fu.*	Obsolete.
		Overtake, *tai.*	**171st Radical.** Depicts "hand" grasping "tail."
		Short-tailed birds, *chui.*	**172d Radical.** See No. 13.
		Birds chattering, wrangle, *ch'ou.*	"Bird" duplicated.
		Flock of birds, *tsa, tso.*	Obsolete.
		Rain, *yü.*	**173d Radical.** See No. 89.

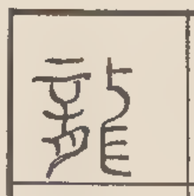
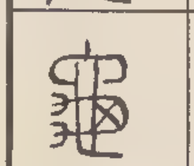
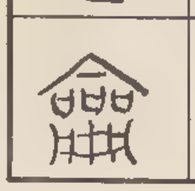
Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
		Cloud, *yün.*	See No. 90.
		Red>clear>sky color>blue-green, *ch'ing.*	**174th Radical** (exhibits a curious succession of meanings).
		Not right, not, *fei.*	**175th Radical.** See No. 386.
		Face, *mien.*	**176th Radical.** See No. 30.
		Leather, *kê, kei.*	**177th Radical.**
		Leather thongs, *wei.*	**178th Radical.** See No. 197.
		Leeks, *kiu.*	**179th Radical.** See No. 116.
		Sound, note, *yin.*	**180th Radical.** See No. 277.
		Head, book-leaf, *yê.*	**181st Radical.**
		Ought, *hsü.*	
		Urgent, *p'in.*	
		Wind, *fêng.*	**182d Radical.**
		To fly, *fei.*	**183d Radical.** See No. 63.
		Food, eat, *shih.*	**184th Radical.**

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	首	Head, *shou.*	**185th Radical.** See No. 29.
	香	Incense, fragrant, *hsiang.*	**186th Radical** is not a Shuo Wên classifier.
	馬	Horse, *ma.*	**187th Radical.** See No. 4.
	骨	Bone, *ku.*	**188th Radical.**
	高	High, *kao.*	**189th Radical.** See No. 305.
	郭	Redoubt, *kuo.*	Space between inner and outer city gates. Modern form has "city" added.
	髟	Human hair, *piao.*	**190th Radical.** See No. 40.
	鬥	Wrangle, *tou.*	**191st Radical.** Depicts "hands" contending.
	鬯	Ghost, spirits, *ch'ang.*	**192d Radical.** See No. 370.
	鬲	Large incense tripod, *li, kê.*	**193d Radical.** See No. 373.
	鬻	Variant of last.	
	鬼	Demon, *kuei.*	**194th Radical.** See No. 354.
	魚	Fish, *yü.*	**195th Radical.** See No. 8.
	魚魚	Large fish (generic), *yü.*	Intensive of last. Obsolete.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	鳥	Long-tailed bird (generic), *niao.*	**196th Radical.** See No. 12.
	鹵	Salt, rude, *lu.*	**197th Radical.** See No. 133.
	鹽	Salt, *yen.*	Synonym of last.
	鹿	Deer, stag, *lu.*	**198th Radical.** See No. 3.
	麤	Fleet, timid, *ts'u.*	Herd of deer.
	麥	Wheat, *mai, mei.*	**199th Radical.**
	麻	Hemp, flax, *ma.*	**200th Radical.**
	黃	Yellow, *huang.*	**201st Radical.**
	黍	Tall millet, growing, *shu.*	**202d Radical.**
	黑	Black, *hê, hei.*	**203d Radical.**
	黹	To embroider, *chih.*	**204th Radical.** See No. 180.
	黽	Toad, *min, mêng.*	**205th Radical.** See No. 9.
	鼎	Small incense tripod, *ting.*	**206th Radical.** See No. 364.
	鼓	Drum, *ku.*	**207th Radical.**

CHINESE IDEOGRAPHS.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	鼠	Rat, mouse, *shu.*	**208th Radical.** See No. 21.
	鼻	Nose, *pi.*	**209th Radical.** See No. 33.
	齊	Growing millet, *ch'i.*	**210th Radical.** See No. 119.
	齒	Front teeth, *ch'ih.*	**211th Radical.** See No. 52.

Shuo Wên, Classifier.	Modern Form.	Meaning and Sound.	Remarks.
	龍	Dragon, *lung.*	**212th Radical.**
	龜	Tortoise, *kuei.*	**213th Radical.** See No. 10.
	龠	Fife, organ, *yüe.*	**214th Radical.**

seem to be groundless. It is unsafe to place absolute confidence in all of the etymologies of the Shuo Wên, but on the other hand, it is a great error to treat it, as has been done by some, as throughout unreliable. Even the compilers of the Kanghsi Dictionary had their doubts about many of the conclusions of the Shuo Wên, as will appear by a perusal of that work. Still upon the whole it seems to have merited the approval of that able corps of scholars.

There are in existence more than one version of the Shuo Wên, which show pronounced variations in the text. This divergence in readings is probably due to the several versions having been derived from early independent transcriptions of the original manuscript. What is needed is a revision of the text, after careful comparison of the extant versions, by a corps of Chinese and foreign scholars, along the lines of textual criticism. To cite an example of divergence in readings, the definition of a certain ancient measure is variously given in two versions, the discrepancy being so great as to leave the reader unable to determine the intended dimensions. Some error in copying is likely the cause of this variation, but just when and where it occurred is the question.

There are also instances where the definition is irreconcilable with subsequent meanings of a symbol. This leads the student to suspect that an early copyist has substituted another character for the one intended. This kind of error is easily made in a language in which the addition or omission of a single stroke may materially alter the significance of a symbol.

Another source of error may be in the imperfections of the original manuscript, for it is a matter of tradition that the Shuo Wên was published after the death of the author, thus embodying in the text some inadvertent errors which a review by the author might have eliminated.

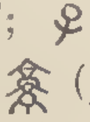
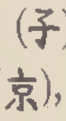
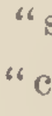
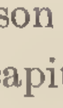
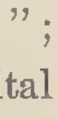
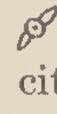
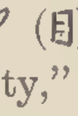
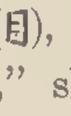
The Chinese commentators of the Shuo Wên have themselves made some ingenious surmises in their efforts to reconcile textual contradictions, and in many instances are free to admit that there must be errors of long standing in the extant versions. Combine the ability of the European textual critic with the accumulated knowledge of the Chinese antiquarian, and some of the knotty questions might find a solution.

In Plates XXX. to XLIX., inclusive, I have given a list of the five hundred and forty "classifiers," which in the opinion of the author of the Shuo Wên is the basis of the later written language. To the form given in the Shuo Wên I have appended the equivalent modern form together with the English definition and the pronunciation. These symbols have been arranged so as to fall under the successive radicals as now accepted by modern lexicographers.

III. THE ROYAL EDICT CONFIRMING THE DOMAIN OF SAN.[26]

Upon the following pages is shown a fac-simile of this edict, as given by Juan Yüan in his work on Old Inscriptions, together with a transliteration into the modern character, and an attempt at translation.[27] According to Juan Yüan this remarkable text of three hundred and fifty-seven symbols was engraved upon a brass tripod originally in the collection of the Hsü (徐) family of Yang Chow (揚州) but later (A. D. 1803) in the collection of one Hung (洪), presumably of the same city. It is accepted as genuine by the scholar Juan Yüan, who seems to have been a discriminating student of old inscriptions. He suggests that the Edict may date back to the reign of Wu Wang 武王 (B. C. 1122). The style of this inscription is in semi-cursive character with but few carefully executed symbols. Contractions and variations are numerous, as will appear by comparing the symbols which occur more than once.

Some of the symbols show an arrangement of their component parts quite different from that of their present form, such as 成 for 土成; 棗 for 棘; 盉 for 相.

Others are still in the pictographic state, such as:  (月), "moon";  (馬), "horse";  (子), "son";  (目), "eye";  (豆), "stemmed dish" (here a man's name);  (京), "capital city," showing the tower over the city gate;  (井), "well," with the mouth still in place; and a fairly good pair of doors in  (門), "gate."

The symbol 義 *i* "public" occurs thrice in such strange forms ( ) that it raises a question as to its derivation from 我 *wö* unless (old form of *wö*) has become mere scroll-work in the old cursive style.

The text may be regarded as rightly belonging to the early date ascribed to it, and I see no reason for suspecting it as a forgery.

We know from history that Wu Wang established the Chou Dynasty 周, B. C. 1122; that he set nine ministers over his realm, one of whom was San I-shêng (散宜生).

The instrument is executed in the form of an indenture, with description of land and names of adjacent landholders as in modern Chinese deeds. The unusual feature is the oath taken by the king and the go-betweens to secure the rights of the clan or family of San. An incidental proof of antiquity is the form of the date, which shows the cycle-signs in use for days of the month[28] instead of the later usage

[26] For convenience this may be designated "The San Edict."

[27] This is but a tentative translation, for a minute study of local geography and history is necessary to throw light upon many points otherwise obscure.

[28] The first year of the 26th cycle coincides with B. C. 1137. This was designated by 甲子. B. C. 112- was 己 . Here we find 乙 , which is the fifty-second year of the cycle and falls outside the reign of Wu Wang (B. C. 1122–1115). Either the assumed reign is incorrect, or else the date-mark applies to a *day* and not to a *year*.

to designate years. This peculiarity, together with the general style of writing, suggest a period at or near that of the "tortoise-shell" inscriptions referred to hereafter. The inscription was presumably on the body of the tripod, and in case it covered the entire surface, the vessel must have been at least three feet in circumference. So heavy a bronze object would be hard to destroy, and this may account for its having survived the ravages of time.

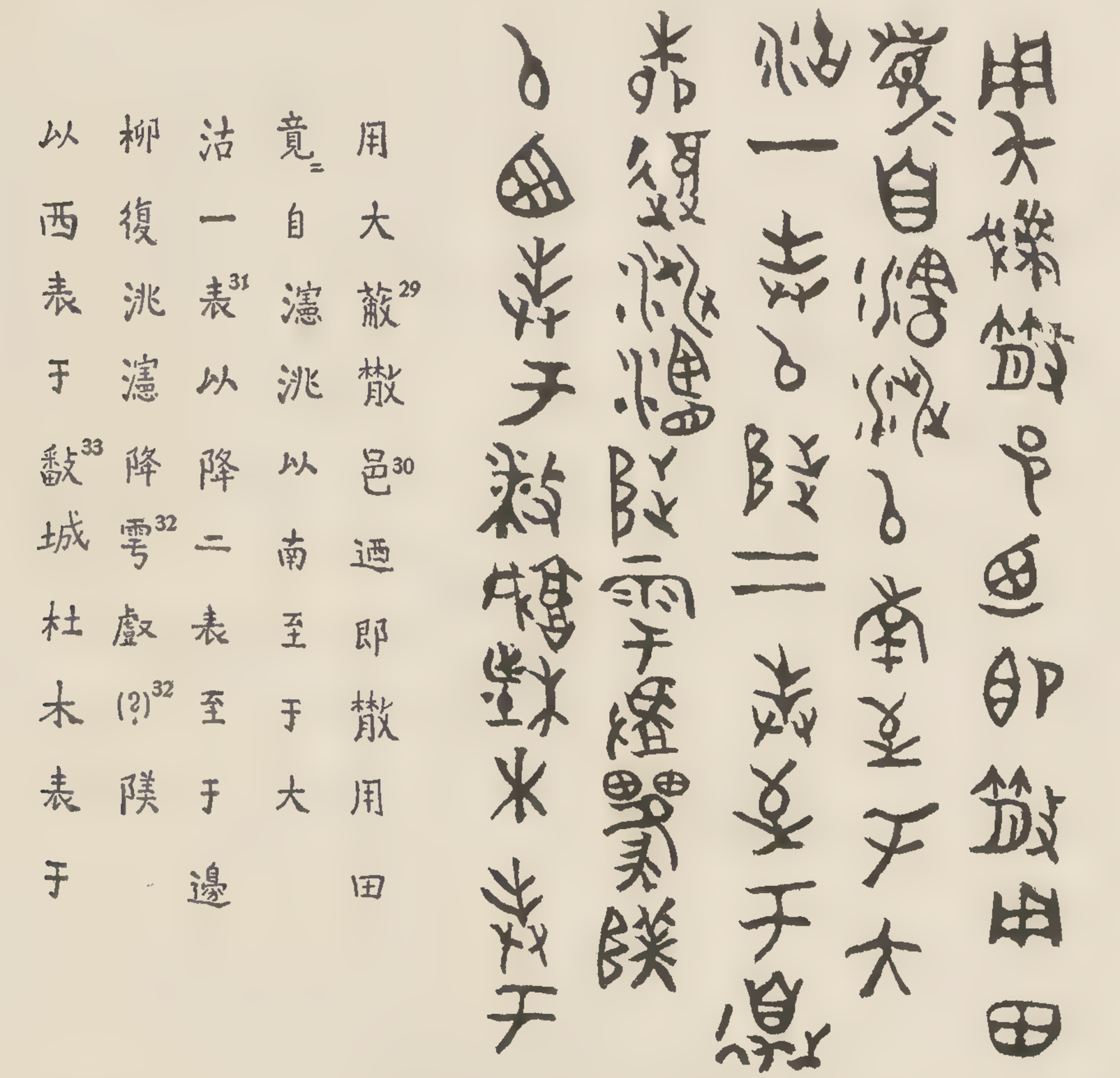
The habit of inscribing bronze vessels and implements was in vogue among the Chinese at a very early date. Inscriptions upon sacrificial vessels are usually in conventional language, affording no valuable historical data. Halberd-heads often have a single symbol engraved or embossed upon the butt, such as that for *halberd, war, army, lightning.* Others have two or more characters giving names of cities, which may be trade-marks. Numerals and dates frequently occur on swords, halberds, and cross-bow triggers, which are supposed to be check-marks made by the inspector of arms. Old bronze hatchets and chisels sometimes have marks cut into the surface, probably for the purpose of identifying ownership. In general, very few Chinese inscriptions of ancient date afford any information of moment. In view of this, the San Edict stands almost alone as an inscription furnishing definite information, unless we except the Standard Weights and Measures of Ch'in Shih Huang-ti (B. C. 240–230), upon which was inscribed the edict for uniformity with the reign and year. Should it be proved that the date affixed to the San Edict is a cycle year-sign, then it must be later than the reign of Wu Wang, and its purport would be the confirmation of title to a domain presumably acquired at an earlier date.

In passing it may be noted that the Chinese cycle consists of a period of sixty years. Each year has a distinguishing title called the "year sign," which is composed of two characters selected from the twenty-two signs known as the Ten Stems and Twelve Branches. Chinese chronology is based upon the succession of the cycles. The first year of the first cycle coincides with the year 2637 B. C., computed from known dates in Chinese history.

There is, however, some doubt as to the exact period when the cycle-system was adopted for fixing the succession of years, and there is much to warrant the supposition that the cycle-signs were in use for *days* long before they became current as *year-signs.* The late Dr. Edkins was of the opinion that these twenty-two symbols were chronological signs imported from Babylonia at a very early time. Just what his proofs were I am unable to state.

TRANSLATION.

Confirmation of the vast territory [29] San-I, [30] being the domain now enjoyed by the said San. Beginning at the Hsien and T'ao Rivers, thence south to the Ta Ku River, a land-mark ; [31] thence down stream by two land marks to a row of willows ; again down the T'ao and Hsien rivers to Yü Ch'a [32] and (?) Mei ; [32] thence west, bounded by Po [33] Ch'êng (city) to an apple tree ; thence



[29] 蔽 here means "territory," an unusual sense, now obsolete (*cf.* Kanghsi).

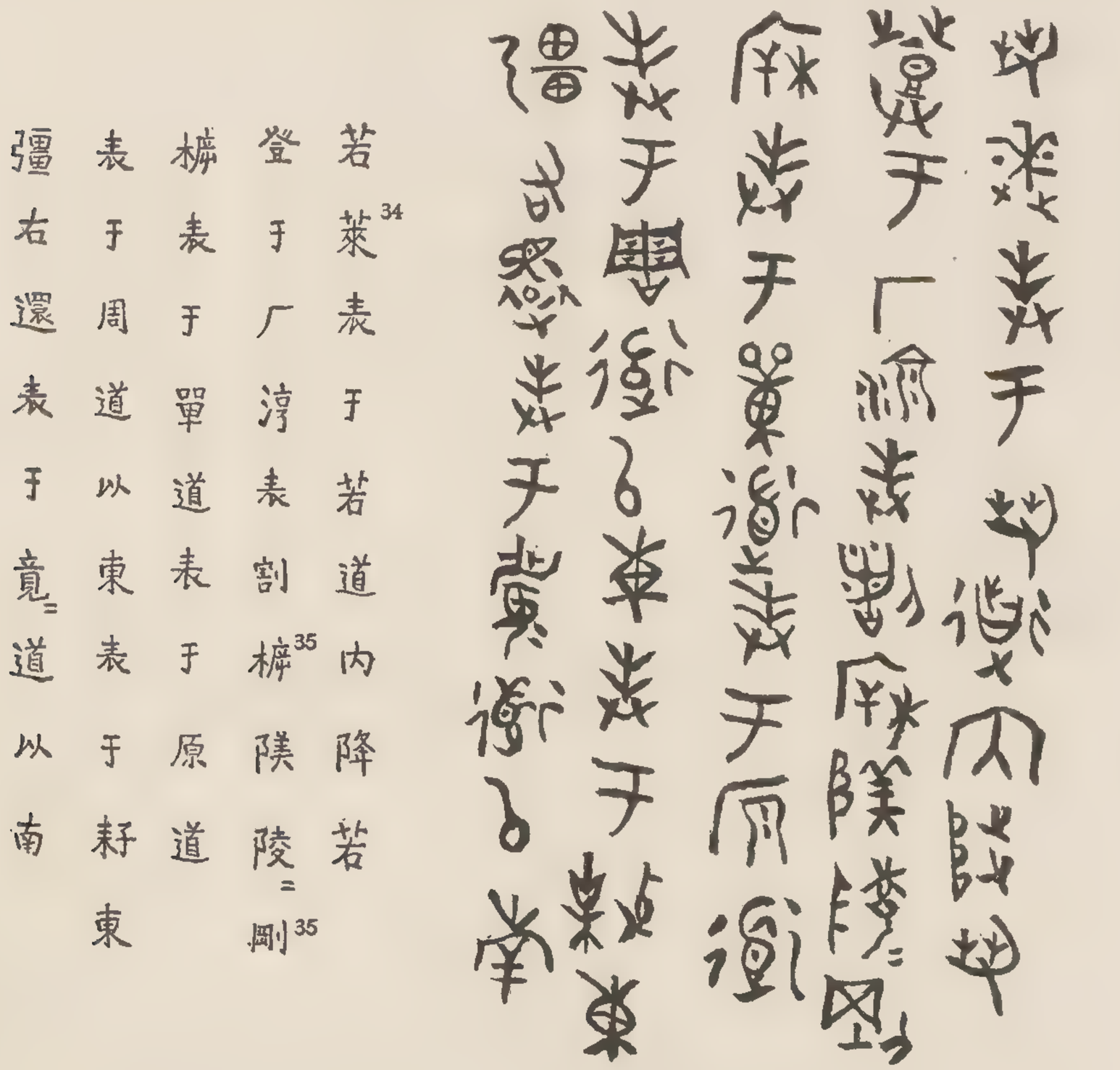
[30] "I" (邑) is "judicial district" (now a county), so San-I is the jurisdiction of San.

[31] "Landmark" (表) *piao*, was originally a bush or tree marking farm lands. Kangshi illustrates it : "To set a tree as a *piao*" (立木為表). Here the symbol is a pictograph (). It seems to have also a verbal meaning.

[32] 雩 虡 and (?) 陑. Probably local names. The symbol has not been deciphered.

[33] Old form of 播 *po*. The only geographical name cited under this by Kanghsi is "Marsh in Yü Chou."

along waste lands,[34] bounded by a road, through [said lands] up a cliff by a pool; thence across So Mei Ling and Kang-So [35] along a path, and thence by the former road to the highway; thence east, bounded by Tsï's eastward line, turning to the right to a boundary road; thence south



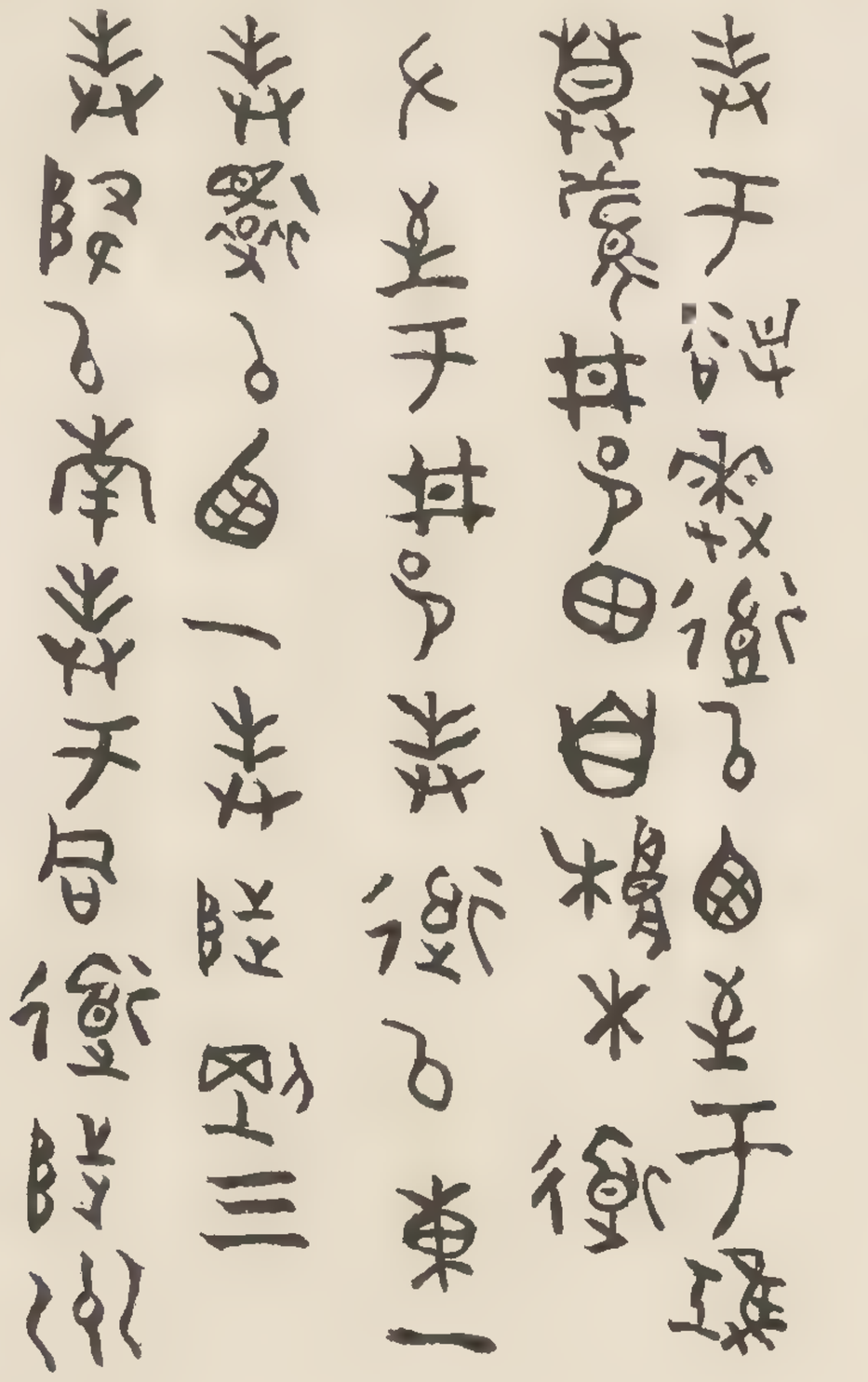
若 登 柍 表 彊
莱[34] 于 表 于 右
表 厂 表 于 于
于 涫 于 原 若
若 表 道 道 還
道 割 道 于 表
内 柍[35] 表 若 于
降 陖 于 道 道
若 陵＝ 道 東 从
剛[35] 表 从 南

[34] "Waste lands" 若 莱. This is a guess. The expression is obscure. 若 may mean "dry grass" and be allied to 莱 "thistle." Both characters have other meanings that are inapplicable here. 𦰡 (若) resembles 𦬊 (艾) *ai*, "artemisia." Full form for 若 is 𦰡. Here contracted.

[35] 柍陖陵 (So Mei Ling) and 剛 柍 (Kang So) are probably local names of ridges.

bounded by the Ki Lai[36] road; thence west to the line of Hung Mu's land to the Government Land Plot,[37] and from a poplar tree on the left of the road up to said Government Plot eastward, along a road as boundary, to a landmark; turning westward along and down Kang past three landmarks, and thence south to the highway down by Chou[38]

表于邻莱道以西至于堆
表還从于井邑田自櫟木道
左至于井邑表道从東一
莫竟井[37]邑田表道从東一
表降从南西一表降剛三
于周道降州[38]

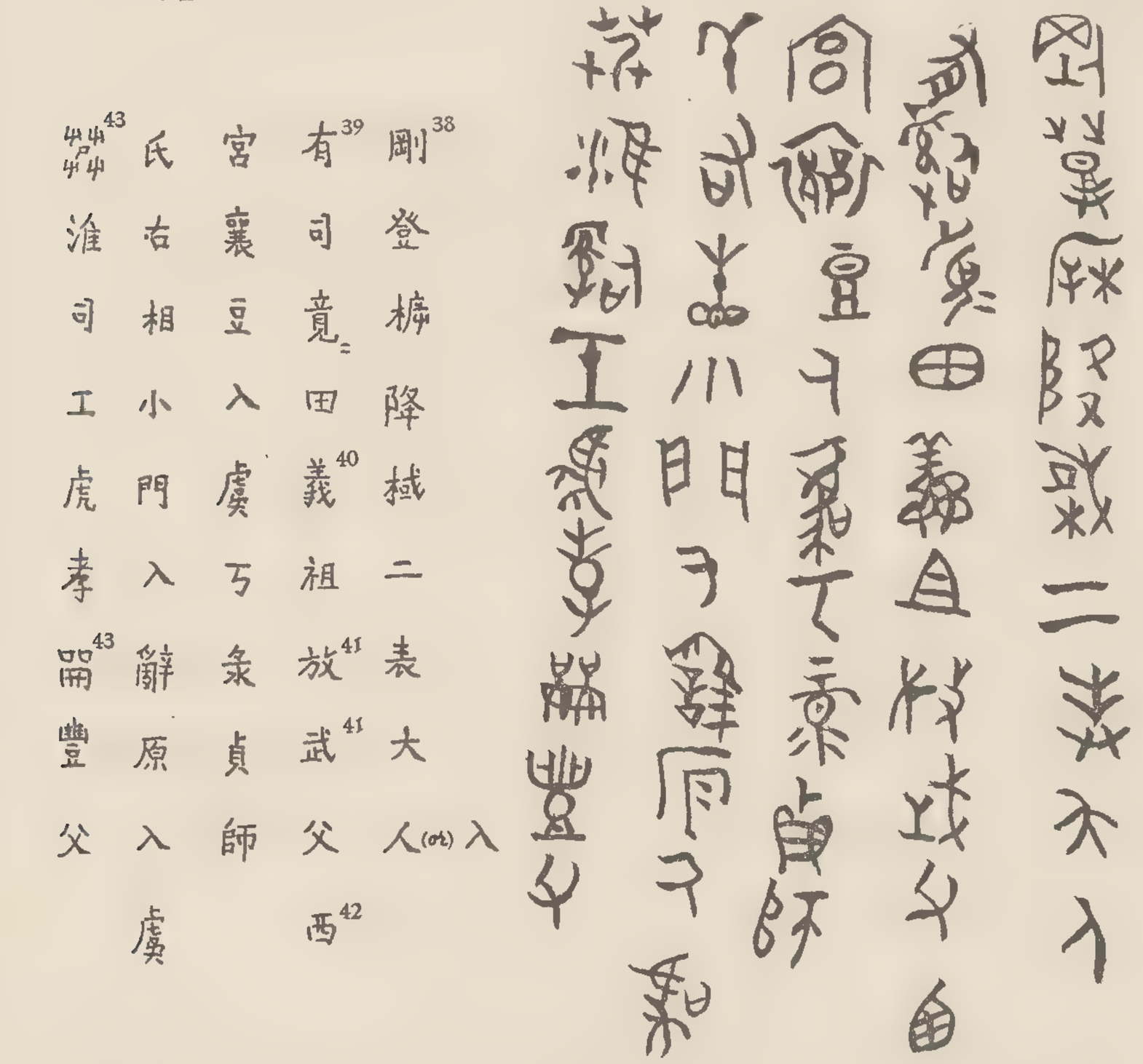


[36] 邻莱 (Ki Lai) is obscure. I take it as a local name.

[37] Government land-plot (井邑田) refers to the ancient government reservation of 100 Mow (acres) out of every 900. Land was divided into nine plots, thus 田. The reservation was in the center and was described by the sign 井, which soon coalesced with the symbol for "well."

[38] The significance of the terms "Chou" and "Kang" (see next page) is uncertain. The former is usually a "judicial district," but here it seems to have special meaning, *e. g.*, personal name.

and Kang, ascending So (a ridge) and down to a thicket and two land-marks, across the holdings of the Yu Sï[39] and honorable elders,[40] Fang Wu-fu,[41] Hsi Kung,[42] Hsiang, Tou, across Yü K'ao, Lu Chêng, clan of Shíh, the private gateway (?) of Yu Hsiang, across Ts'ï Yuan, across Yü, 𠂤𠂤 (unidentified name), Huai, Superintendent of Works Hu Hsiao, (?) Fêng Fu, 豐父



剛[38] 登 桷 降 戠 二
有[39] 司 竟 田 義[40] 祖
宮 襄 豆 入 虞 丂
氏 右 相 小 門 入
淮[43] 司 工 虎 孝
豐[43] 父 辭 原 入 虞
入 大 人(or) 武[41] 父 西[42]

[39] Yu-sï (有 司) "petty officers," "retainers." These officers comprised inspectors and superintendents of many departments under a feudal lord.

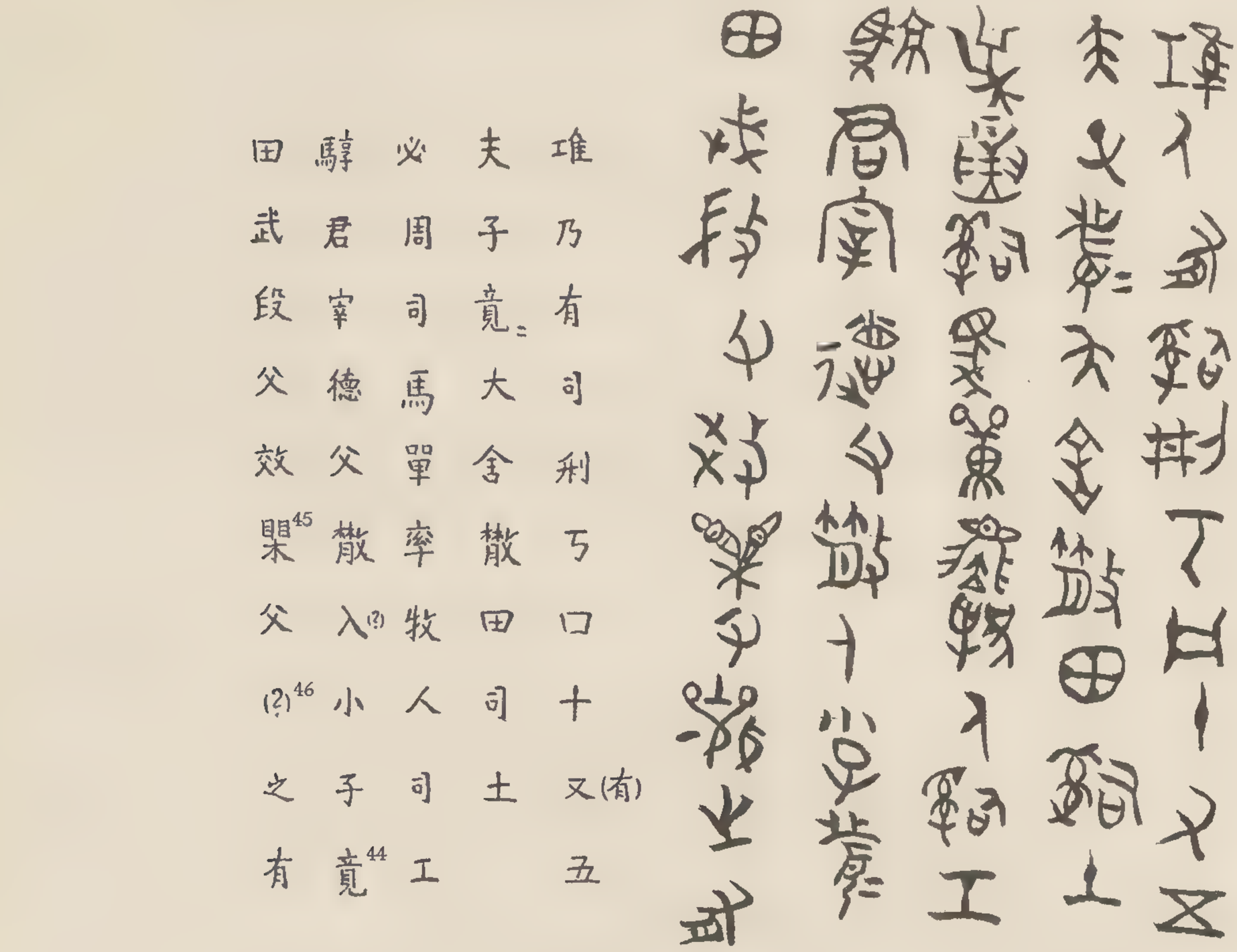
[40] I venture to translate 義 祖 (i-tsu) as "honorable elders," analogous to 公 祖 of like meaning. 祖 usually means "ancestor." The expression "i-tsu" may possibly be a name.

[41] 武 父 (wu-fu) is cited by Kanghsi as a recognized title, but *not defined*. It ought to mean "knight" or "man at arms." Here it is likely a title. 放 (fang) means "release," but ought to stand for a man's name. Kanghsi cites no case of such usage, and Juan Yüan substitutes another symbol without textual authority.

[42] 西 宮 *hsi kung* is "West Palace" and usually refers to the Harem. Here it may be a personal name, or it may signify that the following-named persons were eunuchs, who as a class have great power at Court.

[43] Unidentified symbols not found in Kangsi.

Hung, and also Superintendent of Punishments K'ao Wei, in all fifteen officers. These immediately adjacent to San's domain are: Inspector of Land Pi Chou, Inspector of Cavalry Tan, Chief Herdsman and Superintendent of Works Tun Kiün, Tsai Te-fu, and bordering on the lands of San and the imperial[44] domain,[44] Wu Tuan-fu, Kiao (?)[45] Fu . . .[46]



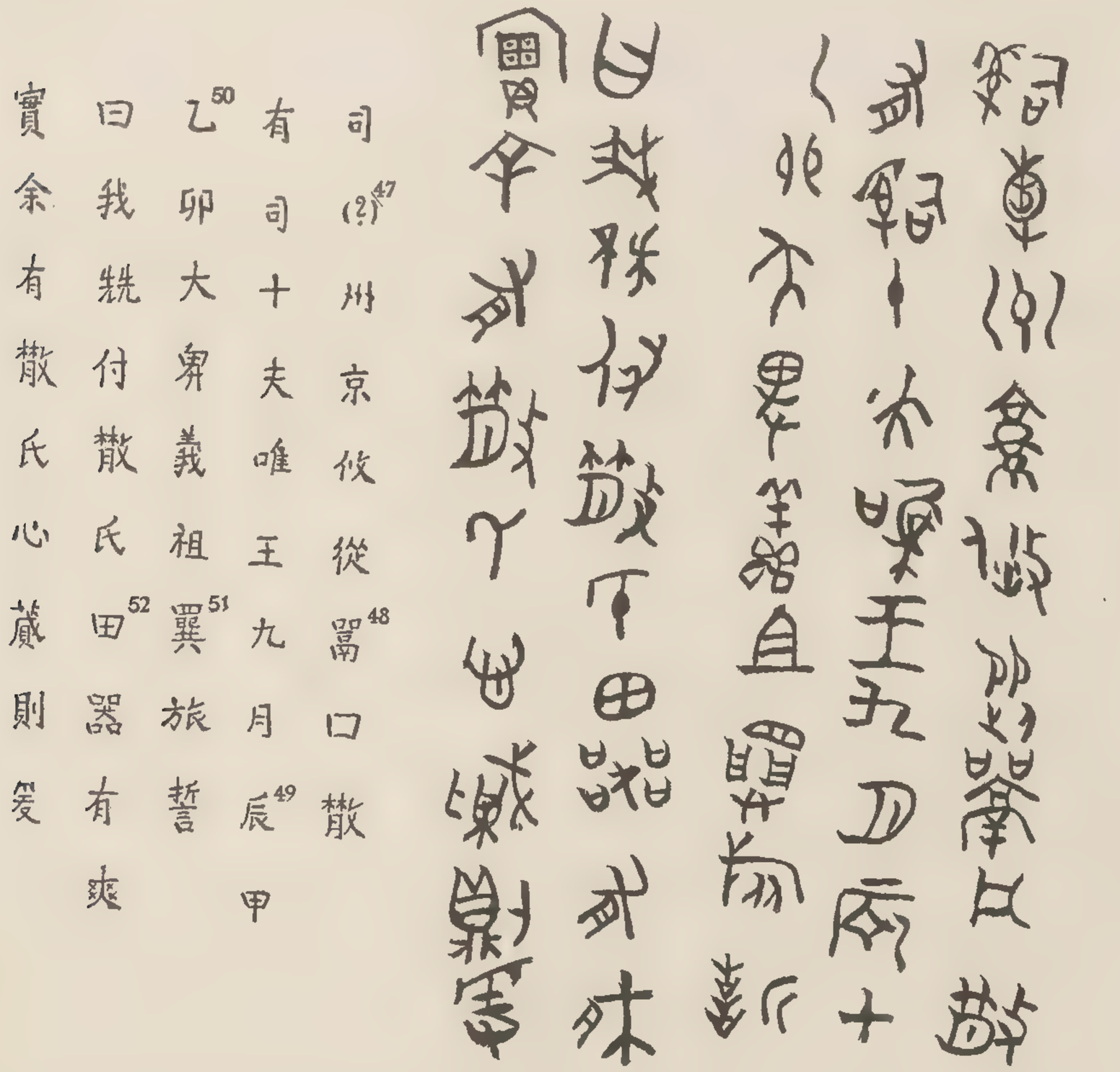
雔乃有司刑于口十又(有)五
夫子竟=大舍散田司土
必周司馬單家散入(?)小子司工
騉君宰德父效父(?)之有竟[44]工
田武段父[45]

[44] This and the preceding descriptive term are perplexing. 竟 田 (king-ti'en) means "to bound land" as elsewhere in this indenture. The preceding expression, *Hsiao tsï*, is an obsolete term of self-depreciation used by an emperor, literally meaning "little child."

[45] The symbol 𣪊 is quite distinct, but is not found in Kanghsi.

[46] The unknown sign is descriptive like on page 28 and may be the same. Both are followed by the possessive 之 and thus modify the following word.

Officer (?)[47] Chou-King (? 州京), Yu Ts'ung (?)[48] Wei (? 冂), San's retainers to the number of ten. Now the King, in the Ninth Moon, Ch'ên-Kia[49] I-Mao,[50] makes oath before [his] Honorable Elders and Select Bannermen,[51] saying, "We confer upon the Clan of San this land-token,[52] securing [the land] to the Clan of San in good faith, else let us suffer



[47] ? is obscure, Juan Yüan makes it 蒙 which seems far-fetched.

[48] A properly formed symbol, but not in Kanghsi.

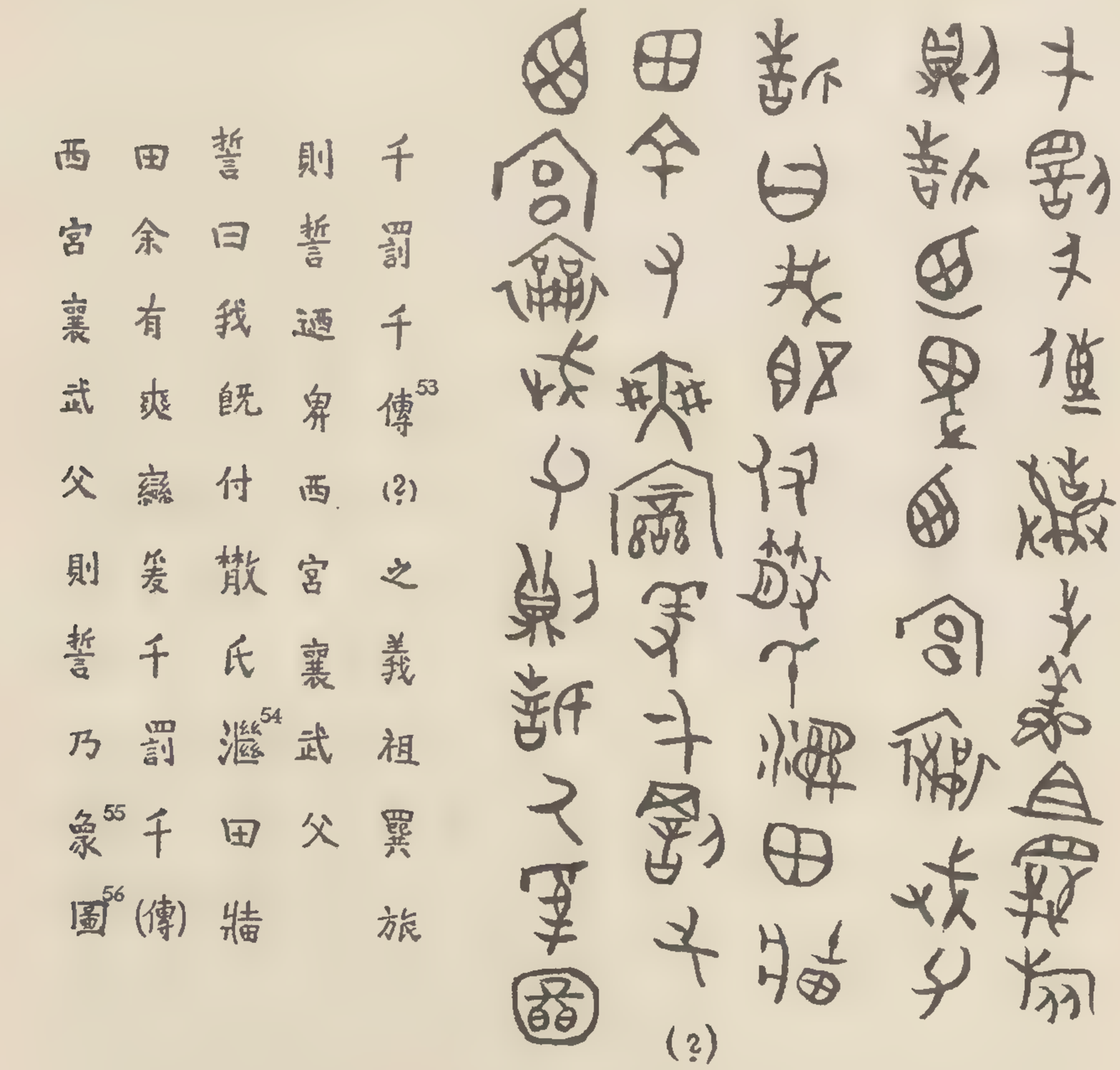
[49] This seems to be a reversed horary couplet like several found in the "tortoise-shell" inscriptions (see *infra*). The sign 十 may be either 甲 *kia* or 在 *tsai* "at." If an horary sign, the two (ch'ên kia) may mean "forenoon."

[50] "I-mao" (乙 卯) refers to the day of the month, and not to the year as in the cycle system (adopted later).

[51] "Select." Kanghsi quotes early use of 翼 *hsüan* as substitute for 選 *hsüan* "select." 旅 *lü* "troops," "bannermen."

[52] 田 器 I take to be "land-token," referring to the tripod inscribed with this indenture, and conferred as a "token" of title to the domain.

a thousand penalties a thousand fold,"[53] . . . Honorable Elders and Select Bannermen in turn make oath to (or) by Hsi Kung, Hsiang Wu Fu saying: "We insure to the Clan of San possession of the lands irrigated (?)[54] and walled, else let us suffer a thousand penalties a thousand [fold]."[53] Hsi Kung and Hsiang Wu-fu upon thus taking oath affix[55] the seal.[56]



千罰千傳[53] (?) 之義
則誓迺鼻西宮襄
誓曰我既付散氏
田余有爽竊[54]灋田牆
西宮襄武父則誓
乃罰千(傳)牆
象[55]
圖[56]

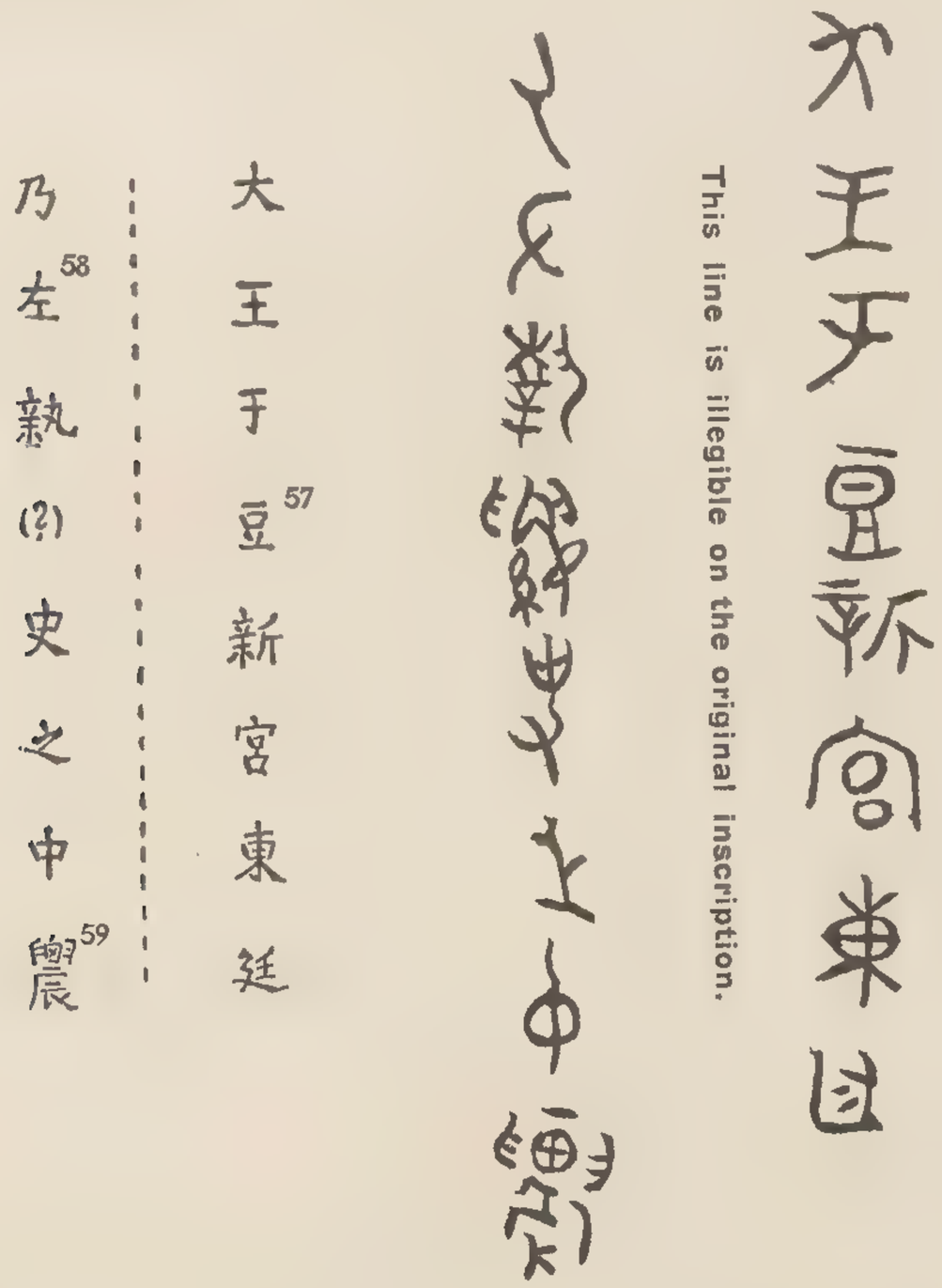
[53] The sign 傳 (ch'uen) "delivered" with 千, means "a thousand times inflicted," *i. e.*, "a thousand fold." In the second oath this sign has been accidentally omitted either by the original engraver or copyist.

[54] The sign 灋 is unquestionably 灋 and is composed of "water" and "connect." It is not in Kanghsi, but might mean "water-system" or "irrigate." 牆 is contracted form of 牆 *ts'iang* "wall." The two expressions each containing 田 (t'ien) "field" may be names of localities.

[55] 象 (hsiang) "elephant" > "ivory" > "carve" > "delineate." Here it probably means "affix."

[56] 圖 (t'u) "seal," "diagram." No seal is shown in this copy of the edict. Possibly a "map" of the domain accompanied the edict.

The Great King, with Tou,[57] in the New Palace, East Audience Hall. . . . on the left[58] the Royal Secretary, with the Minister of Agriculture between.[59]



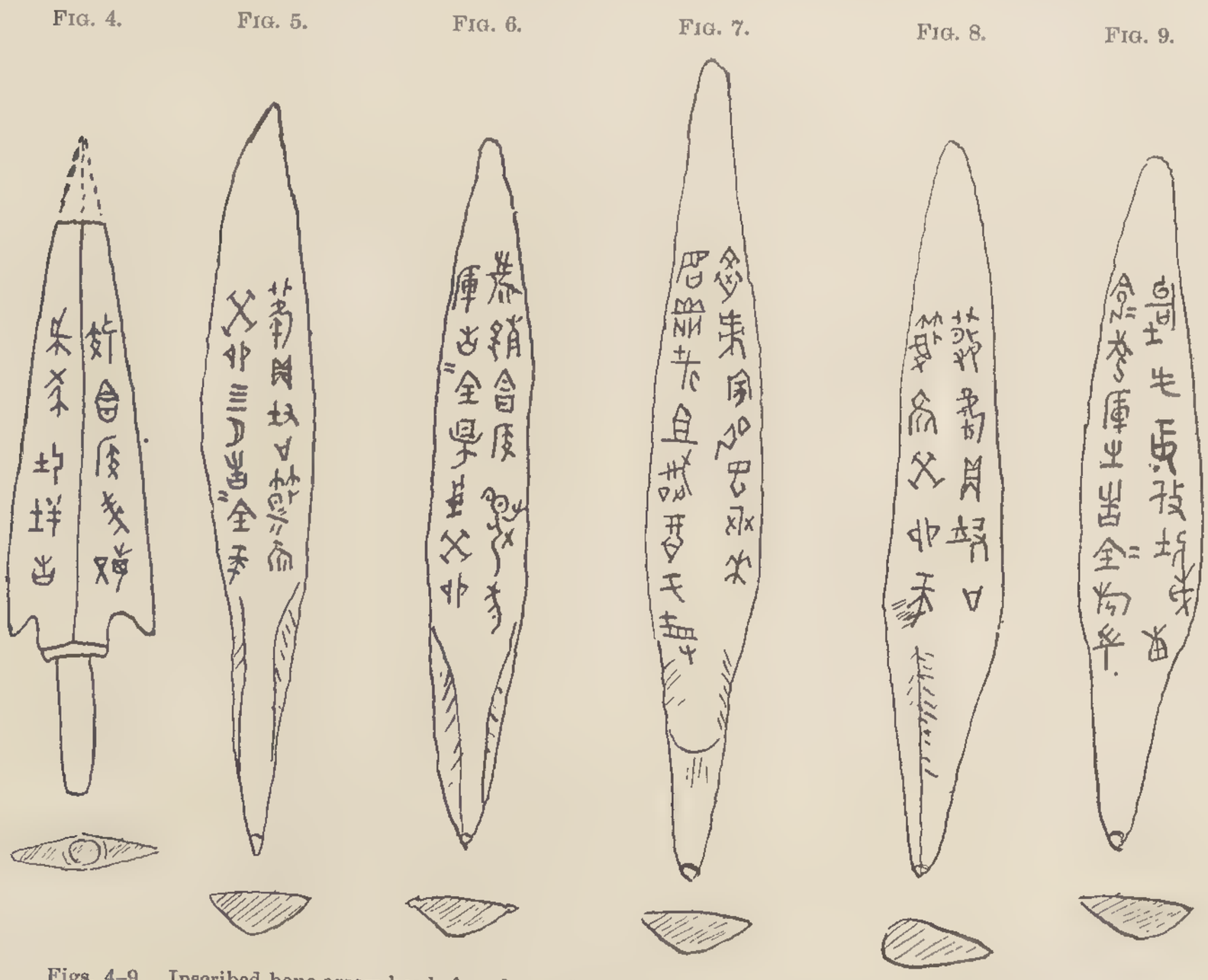
[57] Probably the go-between, as yet in China in all such transactions. This name appears on page 25 as one of the retainers of San.

[58] Tradition makes the *right hand* the ancient seat of honor, hence properly that of the *King*. A trace of this usage is in the Chinese army, where the *right*-wing (右 軍) takes the precedence. Modern custom makes the *left* the seat of honor.

[59] I make the last symbol in the edict as above shown, "Minister of Agriculture." Old form of 農 should be 𢆶, which closely resembles 𣪊. Modern form is 農 (nung) "farmer." Kanghsi says: "Also title of officer over agriculture" (又司農官名). Juan Yüan makes it 𢆶 without orthographic evidence. In either case the expression is not grammatical.

IV. ANCIENT INSCRIPTIONS UPON BONE AND TORTOISE SHELL.

A remarkable find of antiquities occurred in 1899 near Wei Hui Fu (Honan Province) upon the site of the ancient city Chao Kuo Ch'êng (朝歌城). There were reported to have been exhumed three thousand fragments. The vendors went first to Peking, but finding that city disturbed by the approaching Boxer Uprising, they brought their curios to the city of Weihsien (Shantung) and left a portion of the find in



Figs. 4–9. Inscribed bone arrow-heads found near Wei Hui Fu (Honan Province). Figs. 4–6 are in the Museum of the Royal Asiatic Society at Shanghai, and Figs. 7–9 are in the Bergen collection (Shantung, China). (Slightly reduced in size.) The style of writing is very archaic, most of the symbols being as yet undeciphered.

the hands of a local merchant. This Chinese gentleman, being a friend of the writer, made known the presence of these unique curiosities, and loaned them to him for inspection. The balance of the find had been taken to Shanghai (or elsewhere) and sold to a mandarin (Tao-tai) Liu T'ie-Yün (劉鐵雲). This Chinese scholar published a book in his own language, illustrated with eight hundred phototypes taken

from ink-rubbings of the specimens in his possession. Meanwhile some four hundred fragments were purchased by the writer for the Museum of the Royal Asiatic Society, Shanghai. A year later (1904–5) the remaining eighteen hundred frag-

FIG. 10.

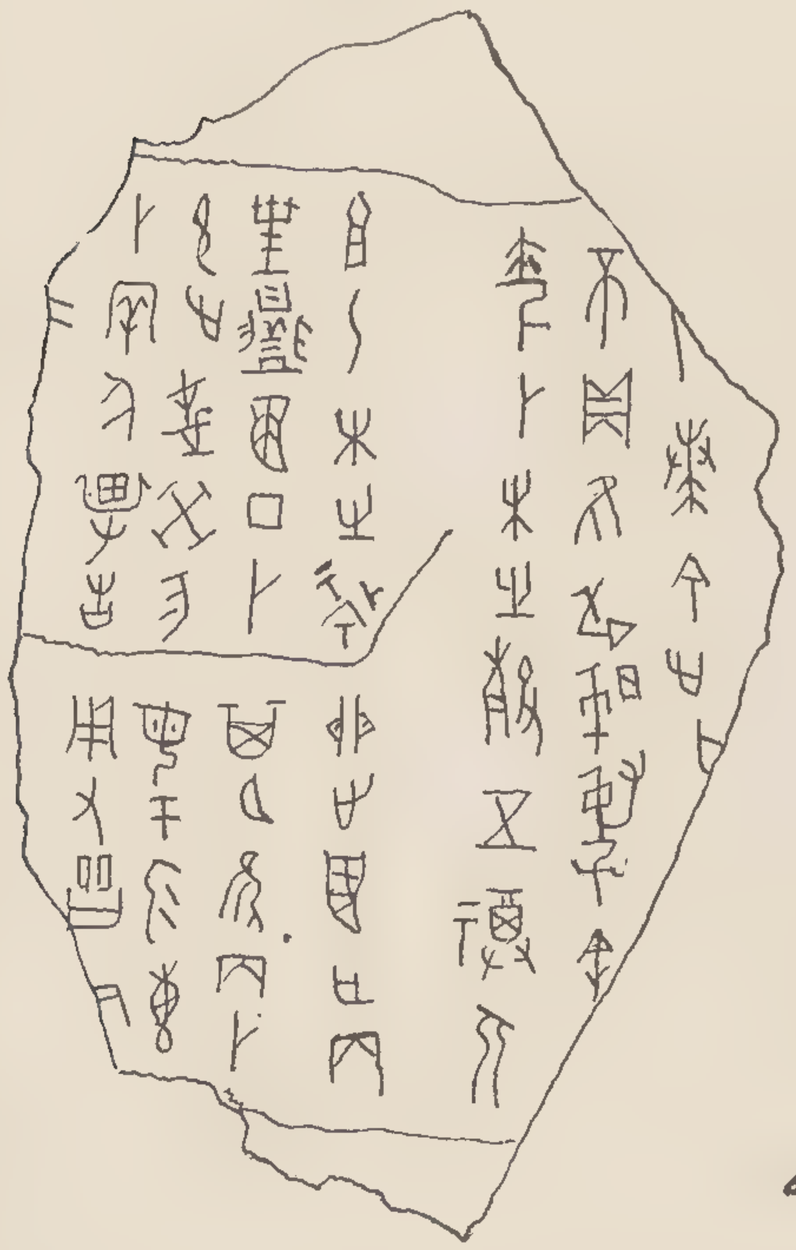


FIG. 11.

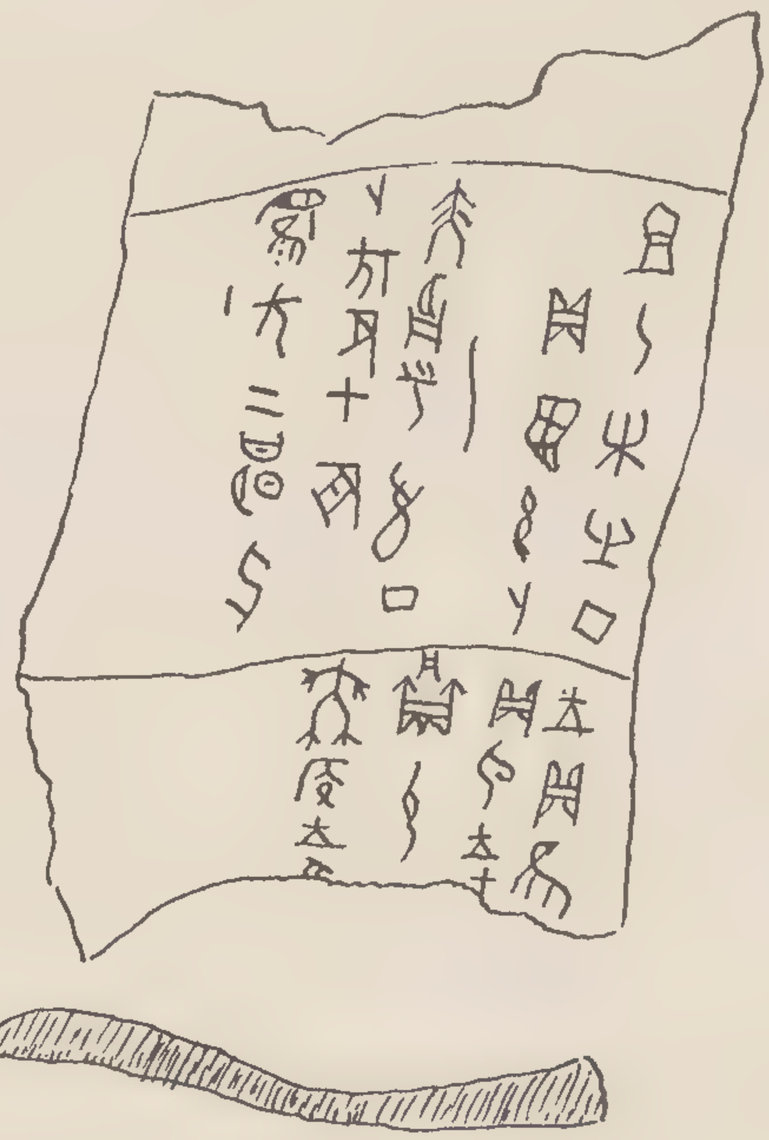


Fig. 10 is a fine specimen of ancient inscribed tortoise-shell, most of the symbols of which are intelligible, but the translation difficult owing to the incompleteness of the inscription. (Actual size.)

Fig. 11. Inscribed bone fragment. The upper right two lines read: 祖乙未之丁問角巳卜. (Technical language of divination containing date of inquiry.)

Originals of Figs. 10–11 in the Couling-Chalfant Collection, Shantung, China. (Actual size.)

ments were located, and, after some difficulty, were procured and are now preserved as private collections. It is unfortunate that the finders did not undertake to match the fragments before disposing of them, for it is an almost impossible task to do this now, on account of the dispersal of the pieces.

While it is a tradition among the Chinese that tortoises and sacrificial bones were once used in divination, yet, according to Liu T'ie-Yün, no one prior to himself had published any account of the discovery of such objects. He further records his opinion that the style of writing is older than that of any extant inscription.

It is possible that this archaic style of writing survived among soothsayers long after it ceased to be in current use. Whatever be the date of the inscriptions, they

FIG. 12. FIG. 13.

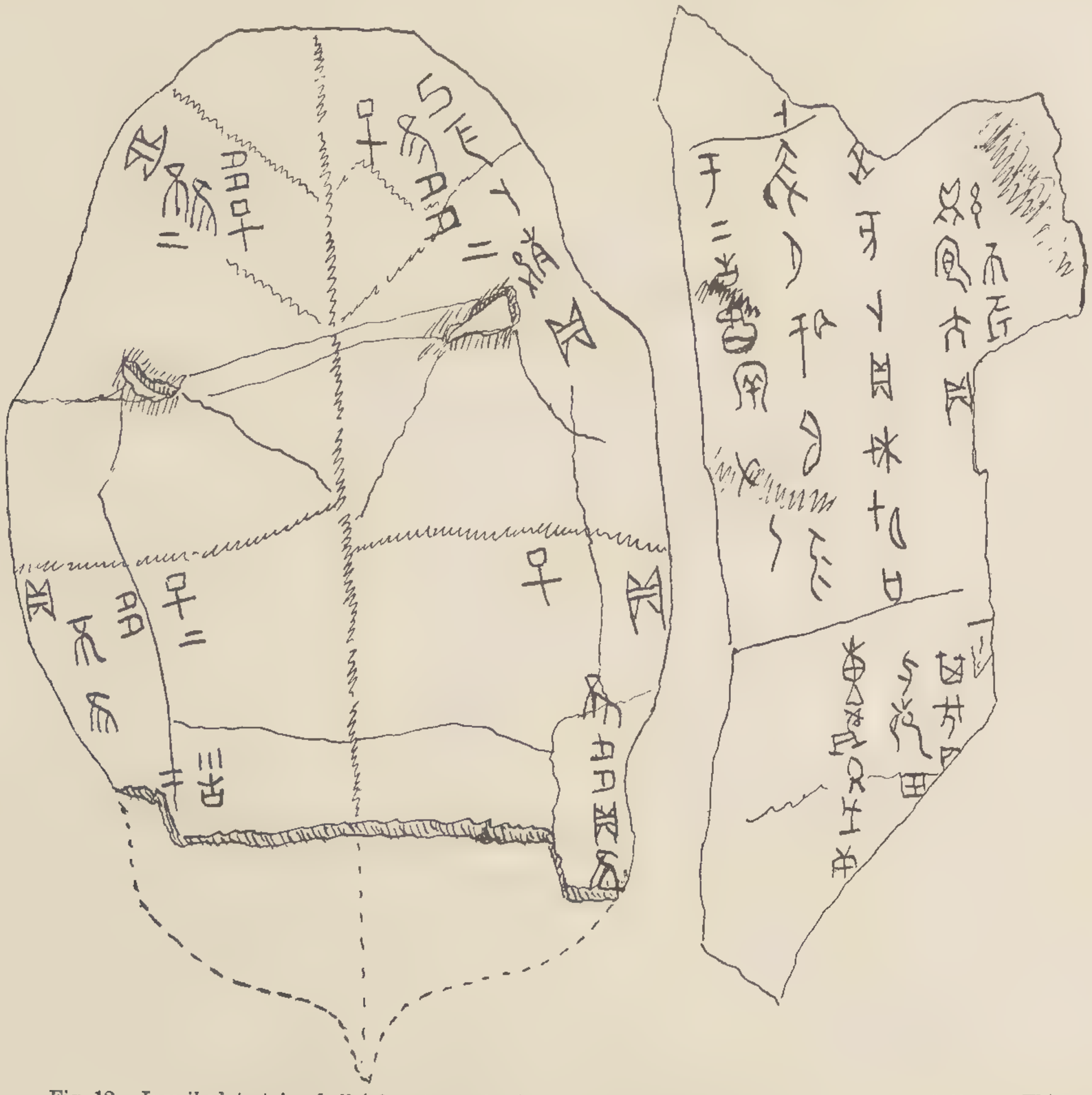


Fig. 12. Inscribed tortoise-shell (almost complete). The part missing is indicated by dotted lines. This was pieced together from several fragments. The four sentences are alike in tenor. Upper right reads: 己亥卜厥問唯多子二. Date (己 亥) and enquiry as to extent of progeny. The two left-side sentences contain 不 "not," and 吉 "lucky." (Actual size.)

Fig. 13. Inscribed tortoise-shell fragment. (Actual size.)

(Originals of Figs. 12–13 in the Couling-Chalfant collection.)

are undoubtedly written in a very primitive form of symbols, many of which are actual pictographs. Only a few illustrations are here given to show the general

style of the writing used. More than six hundred signs have been noted, the most of which are (as yet) undeciphered. Some of the most striking pictographs are the following:

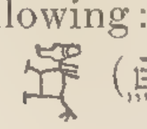
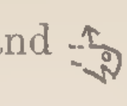
 (馬 "horse"); (?); (dragon?); (?); ("man"? or "heaven"?); and (stag?); and  (bird?); (scorpion?); (rat?) or (tiger?); (symbols relating to plant-life); (?);

FIG. 14.

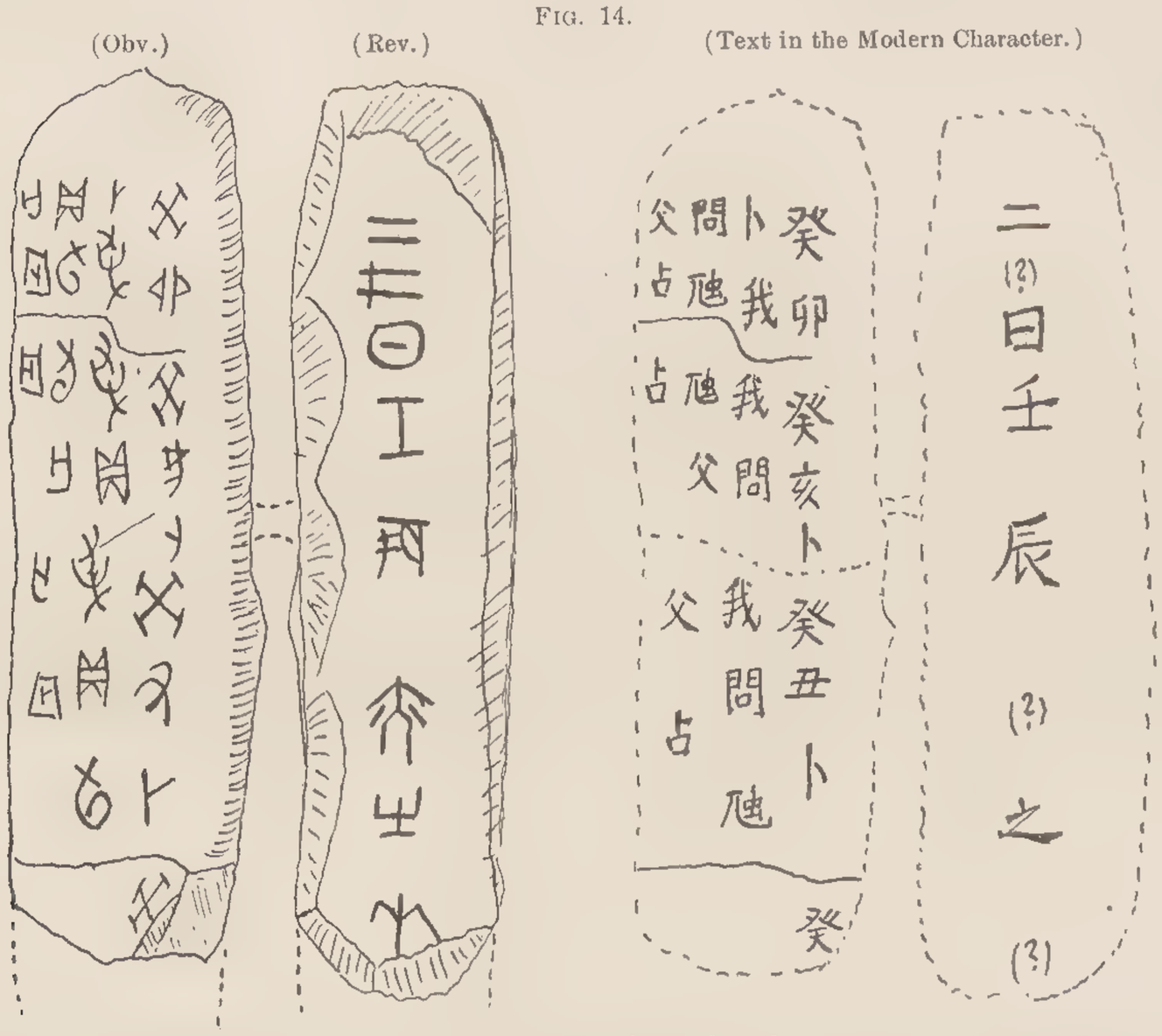
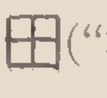
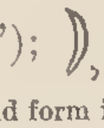


FIG. 14. Inscribed bone, with lower end missing. The obverse has three separate sentences differing only in the dates. The rendering is: "[Date] divination. I ask the Serpent-father to enquire." It appears that at least four enquiries are recorded, inasmuch as the sign at the bottom begins what was probably the same formula with a new date. Liu T'ie Yün interprets "Serpent-father" as a mystic title of the soothsayer. The reverse records a date (壬 辰) and undeciphered signs. This fragment shows discoloration from fire. (Actual size.)
(Original in R. A. Soc. Museum, Shanghai.)

(京? "capital city"); (車 "chariot"); (halberd); (bow); (balances?); (酉 wine-jar); (尊 (?) reverence); (山 "hill");  ("field"); (角 "horn");  (月 "moon"); (囿 "park").

[60] A common old form inverted.

FIG. 15.

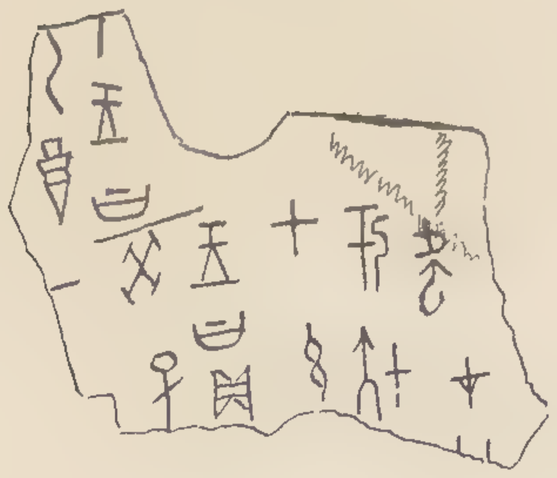
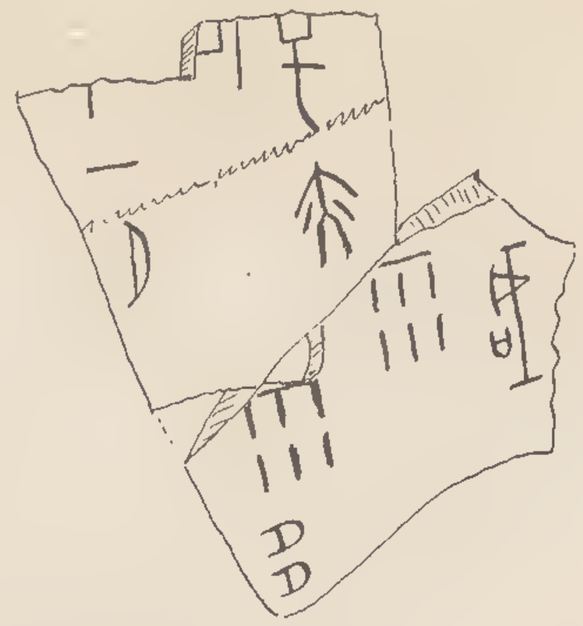


FIG. 16.

FIG. 17.



Figs. 15–17. Inscribed tortoise-shell fragments. (Actual size.)

That these are pictures, even the most skeptical observer will admit. Their precise significance is hard to determine. Some of these pictographs occur more than once, but often without sufficient context to warrant a conclusion as to meaning. I suspect that some signs like 角 küe, 田 t'ien, 箕 ki, 心 hsin, 女 nü, 室 shih, 井 ching, have astrologic significance, being names of stars and constellations.

Enquiries for divination seem to have been made concerning parents, sons, daughters, animals, crops, and utensils. One inscription seems to read 問 立 臣 "Ask selection of Prime Minister." Should this prove correct it suggests consultation of the oracle by royalty. A Chinese scholar mentions a tradition that the

FIG. 18.

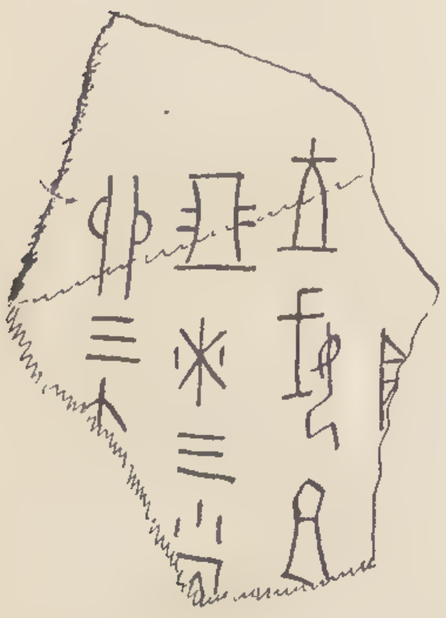


FIG. 19.

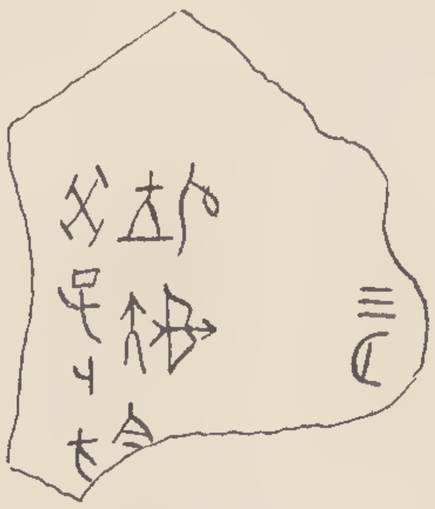
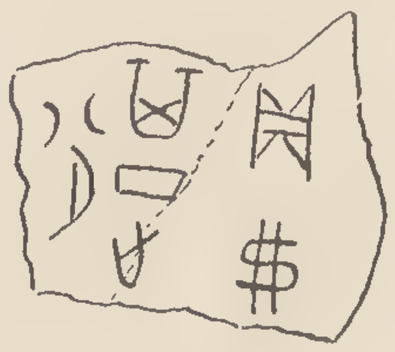


FIG. 20.



Figs. 18–20. Fragments with certain striking symbols, *e. g.*, 𝍐 (a curious coincidence in form with our modern dollar-sign). Here it is 𝍐 (fu) "not." Occurs also as 𝍐, 𝍐, 𝍐. (Actual size.)

(The originals of Figs. 15–18 are in the Couling-Chalfant collection. Figs. 19 and 20 are in the Bergen collection.

oracle of Wên Wang (circa 1200 B. C.) was at Chao Kuo Ch'êng, where the bones were discovered. There is no adequate proof, however, that these inscriptions belong to so early a date.

The cycle-signs (the so-called Ten Stems [十干] and Twelve Branches [十二支] combined in pairs) occur frequently, but as the combinations exceed in number the sixty pairs of signs allotted to the cycle, I infer that they do not conform to the use of these signs as designating years, and are intended to signify the days of the season, or of some period less than a year.[61] In several cases these pairs of characters occur in reversed order, as 申癸 (Shen Kuei) for 癸申, and, more frequently singly, as 丁, 丙, 庚, 己.

At present but little can be said about this unique group of fragmentary inscriptions, the deciphering of which will necessitate a careful study of the traditional methods and vocabulary of astrology and soothsaying as practiced in China. While the Chinese have many works written upon these subjects, still it requires special training in the technical terminology of divination to rightly understand them.

[61] See appended list of these signs (Plate L.).

Regular old forms			Tsï 子	Ch'ou 丑	Yin 寅	Mao 卯	Ch'en 辰	Sï 巳	Wu 午	Wei 未	Shen 申	Yu 酉	Hsü 戌	Hai 亥
十	Kia	甲			十 寅		十 丙	*十			十		十	
乙	I	乙	*乚	乚		乚				乙		乚		乚
丙	Ping	丙			冂		冂 丙	*冂	冂		冂		冂	
丁	Ting	丁	*口	口		口		口	*口	口		口		○
戊	Wu.	戊			戊		戊 丙	*戊	戊		戊		戊	
己	Ki	己	*己	己		己				己		己		己
庚	Keng	庚			庚		庚 丙	*庚			庚			
辛	Hsin	辛	*辛	辛		辛		辛		辛		辛		辛
壬	Jen	壬					工 丙	*工			工		工	
癸	Kuei	癸	*癶	癶		癶				癶		癶		癶

Comparison of the Date-marks found upon the Tortoise-shells with the Year-signs of the Cycle. The year-signs are successive combinations of the ten symbols on the left with the twelve at the top by a method which yields sixty pairs of signs to designate each year of the cycle.

*Couplets not belonging to the cycle-series. Alternate forms are placed side by side.

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OF THE

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VOL. IV. NO. 2.

W. J. HOLLAND, EDITOR.

DESCRIPTION OF THREE NEW SPECIES OF CARANGOID FISHES FROM FORMOSA

BY DAVID STARR JORDAN AND JOHN OTTERBEIN SNYDER

PITTSBURGH.

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DESCRIPTION OF THREE NEW SPECIES OF CARANGOID FISHES FROM FORMOSA.

By David Starr Jordan and John Otterbein Snyder.

The Carnegie Museum has lately bought from Dr. Hans Sauter a fine collection of fishes, obtained by Dr. Sauter from the port of Takao in Formosa. This collection has been placed in the hands of the present writers by Dr. Holland, the Director of the Carnegie Museum, for study and identification.

Among the new species are three, all of the *Citula* group of *Caranx*, which seem to be new. One of these constitutes a distinct genus, *Ulua*. The description of these species constitutes the present paper.

Caranx rastrosus Jordan & Snyder, sp. nov.

(Plate LI.)

Head $3\frac{2}{3}$ in length to base of caudal fin; depth $2\frac{1}{7}$; depth caudal peduncle $5\frac{1}{2}$ in head; eye 4; snout 3; interorbital space $3\frac{1}{2}$; dorsal VII–20; anal III–18; pores in lateral lines about 115.

Anterior profile rising abruptly to occiput from where the slope to base of dorsal is very gradual; interorbital area high, the sharp median ridge about an eye's diameter above orbit; jaws about equal, the lower projecting slightly; maxillary extending to a vertical through anterior edge of pupil; width of posterior edge of maxillary contained $1\frac{1}{8}$ times in suborbital. Minute bristle-like teeth on the jaws, vomer, and palatines. Gill-rakers rather long for *Caranx*, 10–22, those on lower limb of arch short anteriorly, the longest contained 6 times in head. Edges of opercles and preopercles membranous.

Body with very small scales; the throat, breast, a considerable area including base and axil of pectoral, and a narrow space extending back from occiput to base of dorsal naked; minute scales on upper edge of opercle and preopercle and also on cheek immediately below eye. Lateral line with a long curve above pectoral, the curved portion equal to half the length of lateral line; 14 or 15 small plates on tail, each with a low keel and a posterior spine. Base of caudal with 5 pronounced lateral keels, the pair on each of the median one oblique and convergent posteriorly.

First dorsal with 7 spines, the posterior two separate and very small; highest spine $2\frac{1}{6}$ in head. Anterior part of soft dorsal filamentous, the tip when depressed extending beyond base of caudal; median rays also filamentous, the filamentous extending above edge of fin a little over half their length. Anterior rays of anal closely united to form a filament which extends to base of caudal when depressed, the succeeding rays low. Both soft dorsal and anal with a high sheath of very small, thin scales. Ventrals $2\frac{1}{5}$ in head. Pectorals falcate, $2\frac{7}{8}$ in the length. Caudal lobes equal, $3\frac{1}{10}$ in the length.

Color in spirits silvery; median dorsal region dusky, opercle dusky above, axil of pectoral black; filaments of dorsal and anal black, caudal dusky on edges and on posterior border, ventrals tipped with blackish.

One specimen, the type, from Takao, Formosa, in the Carnegie Museum, measures $13\frac{1}{2}$ inches in length. There is also a specimen from Cavite, in the Philippines in the Museum of Stanford University.

This species closely resembles *Caranx plumbeus* (Quoy and Gaimard) from which it differs in having a greater number of gill-rakers (14 on lower limb of first arch in *Caranx plumbeus*) and a black anal.

Caranx formosanus Jordan & Snyder, sp. nov.

(Plate LII.)

Head $3\frac{1}{5}$ in length to base of caudal; depth 2; depth caudal peduncle 6 in head; eye $4\frac{1}{2}$; snout $2\frac{1}{2}$; width interorbital space $3\frac{1}{3}$; dorsal VII–23; anal II–19; pores in lateral line about 127.

Dorsal contour of body almost evenly rounded from tip of snout to insertion of dorsal, there being but a slight elevation at occiput; and a small depression anterior to nostrils; interorbital area slightly higher than diameter of eye, the crest sharp. Jaws equal; maxillary extending to a vertical through anterior edge of orbit, the width of its posterior edge contained $1\frac{1}{4}$ times in the suborbital. Broad bands of fine teeth on jaws, vomer, and palatines. Gill-rakers short and strong,

4–16 on the first arch, those on anterior part of lower limb very short, the longest (near angle of arch) contained $7\frac{1}{2}$ times in head.

Scales very small; base and axil of pectoral, breast, and throat naked; a small isolated patch of minute, partly embedded scales anterior to base of pectoral; cheek and upper parts of preopercle and opercle with small scales; head otherwise naked, the unscaled area extending backward to base of spinous dorsal. Lateral line broadly curved above pectoral, the curved part including considerably more than half of the lateral line; straight part of the lateral line with small, weak plates, those on caudal peduncle scarcely keeled and without spines.

Dorsal with 7 spines, the posterior 2 being small and detached; highest spine $2\frac{1}{3}$ in head. Anterior part of soft dorsal elevated but not filamentous, the height 2 in head; other rays $4\frac{1}{2}$ in head. Anal similar in shape to dorsal; height of first rays $1\frac{2}{3}$ in head, following rays 4 in head. Caudal lobes equal, $3\frac{1}{10}$ in the length. Pectoral falcate, $2\frac{7}{8}$ in the length. Ventrals $2\frac{1}{2}$ in the length.

Color silvery; a small dusky spot at upper edge of opercle; axil black; dorsals, anal, and caudal edged with dusky; ventral and pectoral immaculate.

Described from the type, an example $11\frac{1}{2}$ inches long from Takao, Formosa, in the Carnegie Museum, collected by Dr. Hans Sauter. A similar specimen, differing in no particular from the type, was recorded from Formosa as *Carangus armatus* "with opercular spot present; lobes of dorsal and anal very low" (Jordan & Evermann, Proc. U. S. Nat. Mus., XXV, p. 338).

The gill-rakers, few in number and very short, especially on anterior part of lower limb, are characteristic of the species.

ULUA Jordan and Snyder, gen. nov.

(Type *Ulua richardsoni* Jordan and Snyder.)

This genus resembles the subgenus *Citula* in *Caranx*, differing in the larger, oblique mouth, and especially in the very long gill-rakers, which cause the mouth to appear, when opened, as if full of feathers. The name *Ulua* is Polynesian, being applied to the finest food-fish of Hawaii and Samoa, belonging to this group. *Caranx forsteri* Cuv. and Val.

Ulua richardsoni Jordan & Snyder, new species.

(Plate LIII.).

Head $3\frac{1}{2}$ in length to base of caudal; depth $2\frac{1}{3}$; depth caudal peduncle $6\frac{1}{2}$ in head; eye $4\frac{9}{10}$; snout 3; width interorbital space $3\frac{1}{3}$; dorsal VII–21; anal III–16; pores in lateral line about 90.

Dorsal contour steep from snout to occiput, then rising more gently to base of dorsal; interorbital region high and sharp anteriorly, its edge an eye's diameter from orbit. Mouth very large, the maxillary extending to a vertical through center of pupil, $2\frac{1}{10}$ in head, the width of its posterior edge contained $1\frac{1}{2}$ times in suborbital area; lower jaw projecting prominently beyond the upper; no teeth; gill-rakers numerous, 24 + 54, and extremely long, the anterior ones projecting upward and forward along sides of mouth and base of tongue, small lateral setæ giving them a distinctly feather-like appearance; length of longest ones contained $3\frac{1}{2}$ times in head. Edges of opercles and preopercles membranous.

Scales very small, those on lower half of body minute and partly embedded; head, except a small area on upper part of opercle and preopercle, naked; throat and breast naked, the unscaled area extending upward and including base and axil of pectoral; a narrow naked area extending from occiput to base of spinous dorsal; a low sheath of scales along bases of soft dorsal and anal. Lateral line with a gentle upward curve on anterior half; a conspicuous dorsal branch extending upward to occiput and then backward to near origin of spinous dorsal; posterior part of lateral line with about 20 plates which are heaviest on caudal peduncle where a slight keel and a blunt spine are developed. Base of caudal with an indistinct keel on each side of the median row of plates.

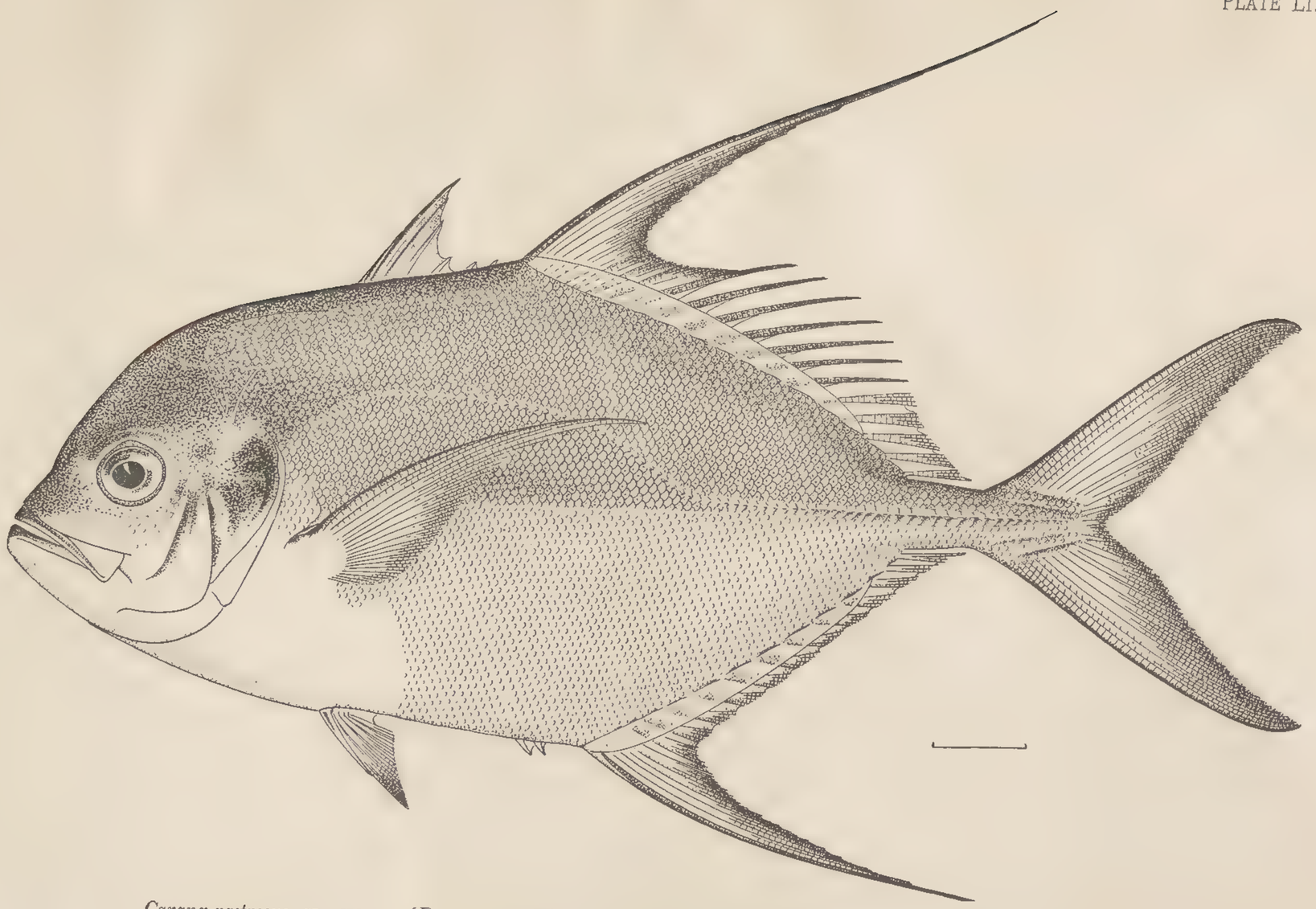
Height of longest dorsal spine contained $3\frac{1}{2}$ times in head, not reaching origin of soft dorsal when depressed, the fin followed by 2 very low free spines; first 5 or 6 rays of soft dorsal elongate, giving the anterior part of fin a somewhat falcate appearance; the following rays about equal in height to diameter of eye. Anal similar in shape to soft dorsal. Caudal very deeply cleft, the lobes equal, their length contained $3\frac{1}{4}$ times in length. Pectoral falcate, $2\frac{2}{5}$ in the length. Ventrals $2\frac{2}{3}$ in head.

Color in spirits bright silvery, somewhat dusky above; axil of pectoral black; median dorsal area from snout backwards dusky; dorsals narrowly edged with dusky; caudal with a dusky margin.

The above description is taken from the type, a specimen 18 inches long from Takao, Formosa, in the Carnegie Museum.

A cotype measuring 9 inches, from the same locality, has the interorbital area slightly lower, the soft dorsal decidedly filamentous, the tip extending backward to middle of caudal fin, and the pectoral more curved and falcate. Other specimens from Cavite, P. I., recorded as *Caranx plumbeus* (Jordan and Seale, Bull. Bureau Fisheries, XXVI, p. 14) do not appear to differ from the Formosan examples.

The species is named for Mr. Robert Earl Richardson, who first recognized the distinctness of the genus.



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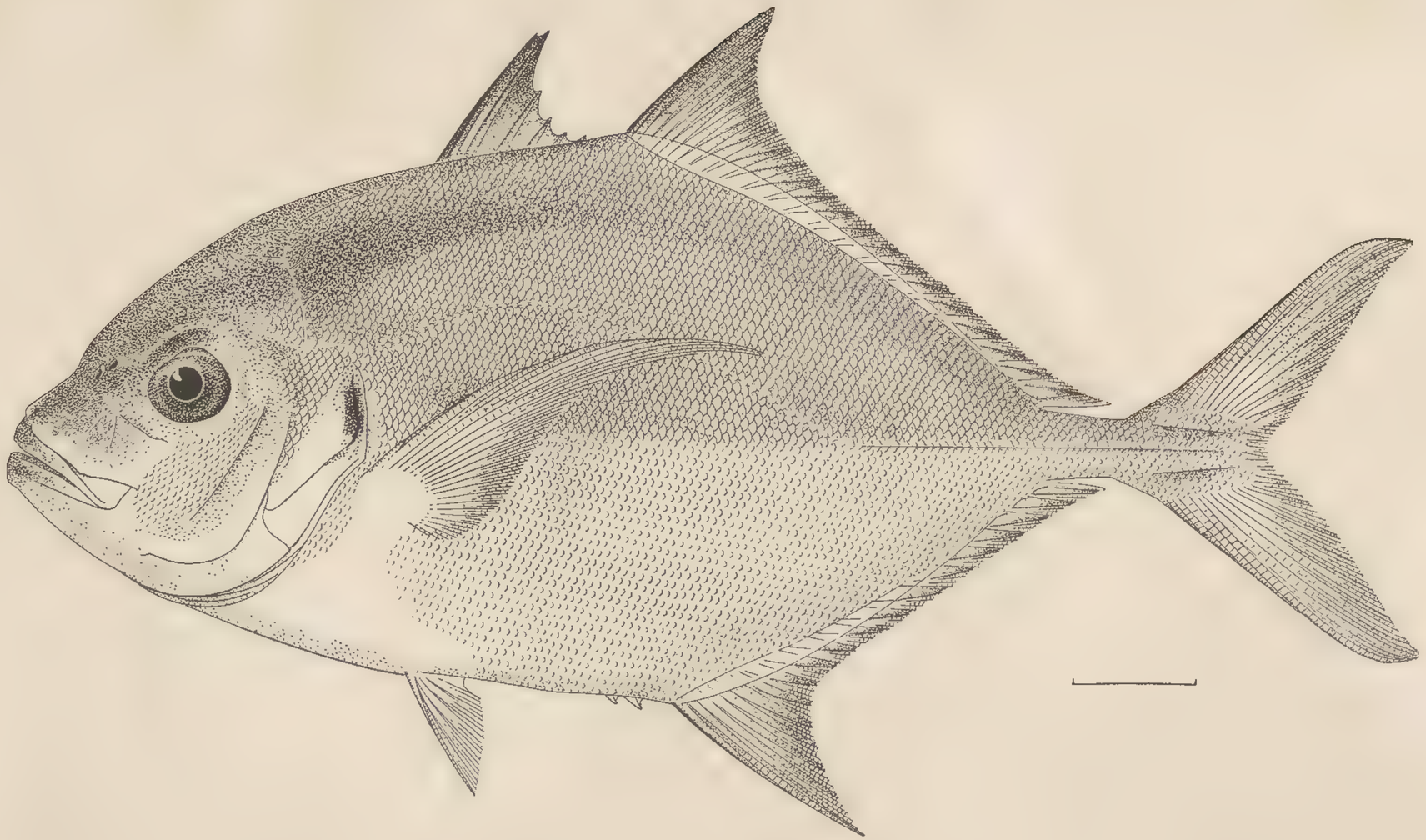

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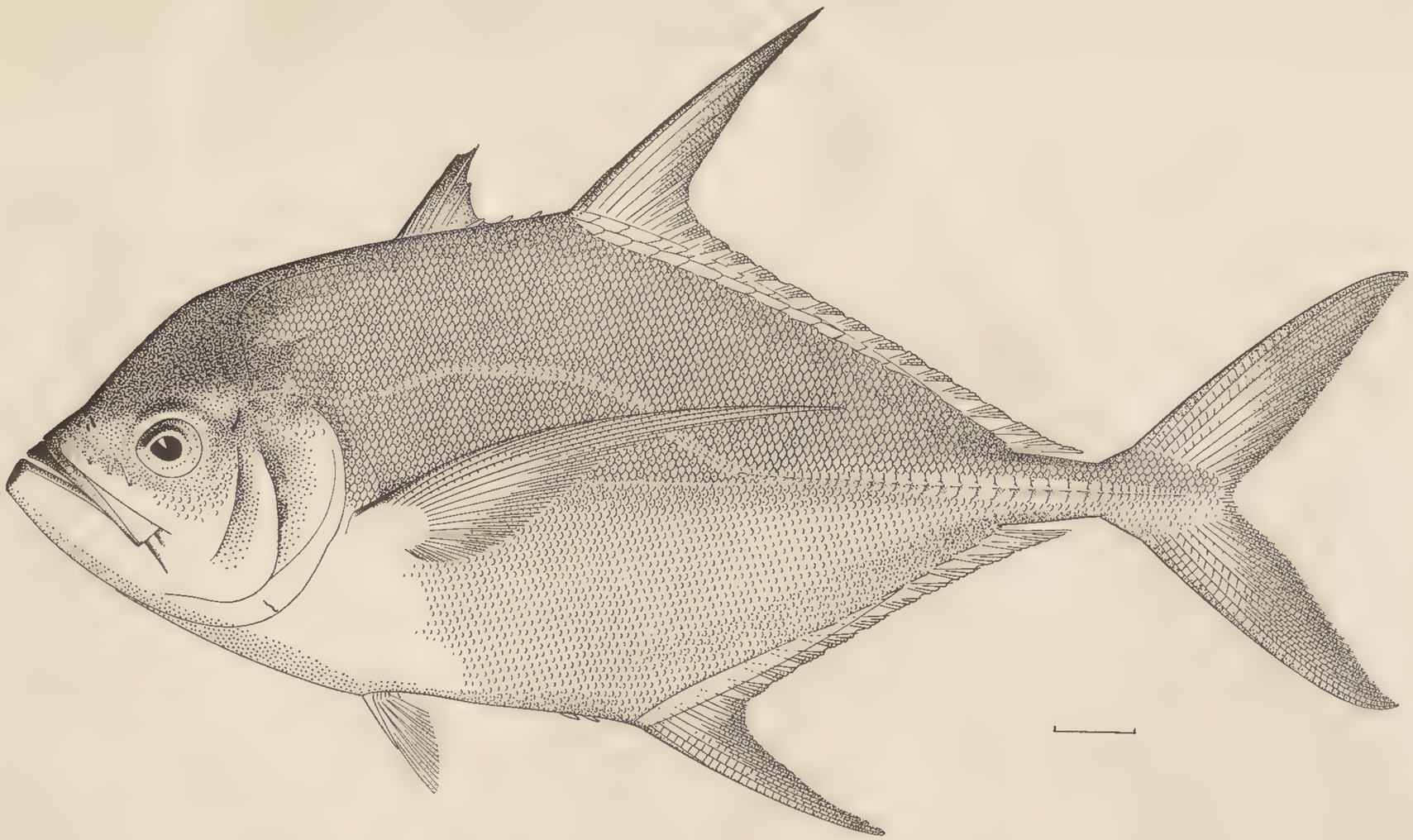

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MEMOIRS

OF THE

CARNEGIE MUSEUM.

VOL. IV. NO. 3.

W. J. HOLLAND, EDITOR.

A REVISION OF THE ENTELODONTIDAE

By O. A. PETERSON

PITTSBURGH.

PUBLISHED BY THE BOARD OF TRUSTEES OF THE

CARNEGIE INSTITUTE.

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MEMOIRS

OF THE

CARNEGIE MUSEUM.

VOL. IV. NO. 3.

A REVISION OF THE ENTELODONTIDÆ.[1]

By O. A. Peterson.

Introductory Remarks.

Since A. Aymard (**1,** pp. 227–242)[2] and S. A. Pomel (**73,** p. 307; **74,** p. 1083) described the genus *Entelodon* from the Tertiary deposits of France, much material has been found, which represents this unique family of mammals, especially in the Oligocene and Miocene formations of the North American Tertiary. The object of the present Memoir is first to give a systematic review of the known genera and species of this family; and secondly to describe and illustrate in detail the type specimen of *Dinohyus hollandi,* which was discovered in the Agate Spring Fossil Quarries, Sioux County, Nebraska, by the Carnegie Museum Expedition of 1905, and briefly described in Science (**78,** pp. 211–212) and the Annals of the Carnegie Museum (**81,** pp. 49–51).

At the very outset of his work the writer became fully aware of the fact that generic and specific determinations in this family have sometimes been based on rather inadequate types, which present few and unsatisfactory characters. Frag-

[1] Pomel's description (73, 74) of *Elotherium* did probably appear before that of Aymard on *Entelodon*, but, inasmuch as the type of the former was rather inadequate, no illustrations were published, and the type has been since lost (see page 43), the present writer is of the opinion that the latter name should be used, as both text and figures are clear.

[2] For the references in parentheses, see the Bibliography appended.

(Published May, 1909.)

mentary types, which very often are most exasperating to the student of paleontology, cannot be regarded as finally determining genera and species, and in the present case we must still await the slow process of discovery before a number of questions can be satisfactorily determined. The paper here presented can only claim to be a report of progress upon our knowledge of this most interesting family, which must be regarded as very distantly related to the *Suidæ*.

The types of the different genera and species of the family, though sometimes very fragmentary, clearly indicate diverging lines. These lines do not possess the radical variability met with for instance in the Merycoidodonts (Oreodonts) and the *Cameloidea*, but they are nevertheless of importance, when the conservative characters of the family as a whole throughout the lower Oligocene are considered.

This paper has been considerably delayed by the fact that the writer in the early part of the year 1908 was suddenly detailed to take charge of the field-work in the Agate Spring Fossil Quarries. The labors in these quarries were rewarded with unusually good success, as has been the case every season since they were first opened by the Carnegie Museum. Among other important material were found a number of portions of individuals of the genus *Dinohyus* which are of great value, as they help to clear up certain anatomical features of that genus which otherwise would have been left in obscurity in the present publication.

For the privilege of study and for aid otherwise given me, I am indebted to Dr. W. J. Holland, Director of the Carnegie Museum, at whose request the present work was undertaken. To Professors Osborn, Scott, Schuchert, and Lull I am indebted for free access to the splendid material of the American Museum of Natural History, the Princeton Museum, and the collection of the late Professor Marsh of Yale. To Dr. W. D. Matthew of the American Museum, Dr. Witmer Stone of the Academy of Natural Sciences, Philadelphia, Mr. J. W. Gidley of the National Museum, Dr. M. S. Farr of Princeton University, Professor John C. Merriam, and Mr. E. L. Furlong of the California University, and Miss Lucy P. Bush recently of Yale Museum, I here wish to extend my thanks and appreciation for important letters and information.

The excellent series of illustrations in the present paper are mainly due to the skilful work of Mr. Sydney Prentice. These illustrations explain many features which, without them, would be quite unintelligible. Most of the photographs except when otherwise stated, were made by Mr. Arthur S. Coggeshall.

Last, but not least, hearty acknowledgment should be expressed to Mr. Andrew Carnegie, the founder of the Institute, whose well-known generosity has made it possible to carry on the work done both in the field and the laboratory.

FAMILY ENTELODONTIDÆ LYDEKKER.[3]

The characters of this group of mammals from the Oligocene and Miocene formations of both the Old and New Worlds amply justified Lydekker (**53b**), Marsh (**64,** p. 408), and Scott (**87,** p. 322) in placing them in a separate family. The combination of the primitive bunodont dental structure with the highly modified limbs and feet gives to this group an unusual and quite unique appearance.

Family Characters: Teeth bunodont. Muzzle long; cranium short. Limbs elongated; feet didactyl.

GENUS ENTELODON Aymard.

There has been much confusion both in Europe and America regarding the priority of the names *Entelodon* Aymard and *Elotherium* Pomel. Quite recently Miss Lucy P. Bush, who was one of Professor Marsh's assistants, wrote an article (**4,** pp. 97–98) which stimulated inquiry as to these two names. After carefully looking over the literature, it is quite plain that Aymard's paper on *Entelodon*, though perhaps written in 1846, was not published until late in 1847 or during the year 1848. The most conclusive evidence of this fact is found on page 247 of Vol. XII, of the Annales de la Société d'Agriculture, des Sciences, et de Commerce du Puy for 1842–1846, or on p. 23 in the reprint of this article. On these pages of Aymard's paper is a foot-note correctly referring to page 385 of the Bulletin de la Société Geologique de France, Vol. IV, which was published late in 1847; consequently Aymard's paper could not have been published in 1846. Pomel's description of *Elotherium* on the other hand was apparently published in 1847; but, in the first place, the type was rather inadequate, judging from Pomel's article; secondly, there is not in Pomel's paper, or elsewhere, any illustration of the specimen; and, thirdly, I am informed that the type is lost.[4] These facts collectively should, in the mind of the writer, exclude the use of the name "*Elotherium*" especially since Aymard's article on *Entelodon* is accompanied with good illustrations of satisfactory types. There was apparently not a great lapse of time between the appearance of the two publications, and it may yet possibly be established that Pomel's description was also delayed and not published before Aymard's paper actually appeared.

Principal Generic Characters of Entelodon: Upper and lower premolars relatively

[3] The family name *Entelodontidæ* was apparently first used by Lydekker in 1883 (**53b,** p. 146), while Edward Richard Alston in the Zoölogical Record for 1876, p. 18, refers to *Parahyus vagans*, *Helohyus*, and "*Elotherium*" under the caption *Elotheriidæ*, without any further note or comment.

[4] Inquiries made by Dr. W. J. Holland while recently in France reveal the fact that the type of *Elotherium* is lost. Professor Marcellin Boule, in a letter to Director Holland, states that he is under the impression that no one, except Pomel himself, ever saw the type. In this connection it is quite significant that in the Catalogue of Vertebrate Fossils in the British Museum, which acquired Pomel's collection, no mention is made of the type of *Elotherium*.

large; posterior portion of the crown of $P^{\frac{3}{3}}$ porportionally heavier than in *Archæotherium*; the crown of $P^{\frac{4}{4}}$ with antero-internal angle of comparatively greater development, which gives the outline of the tooth a more nearly square appearance

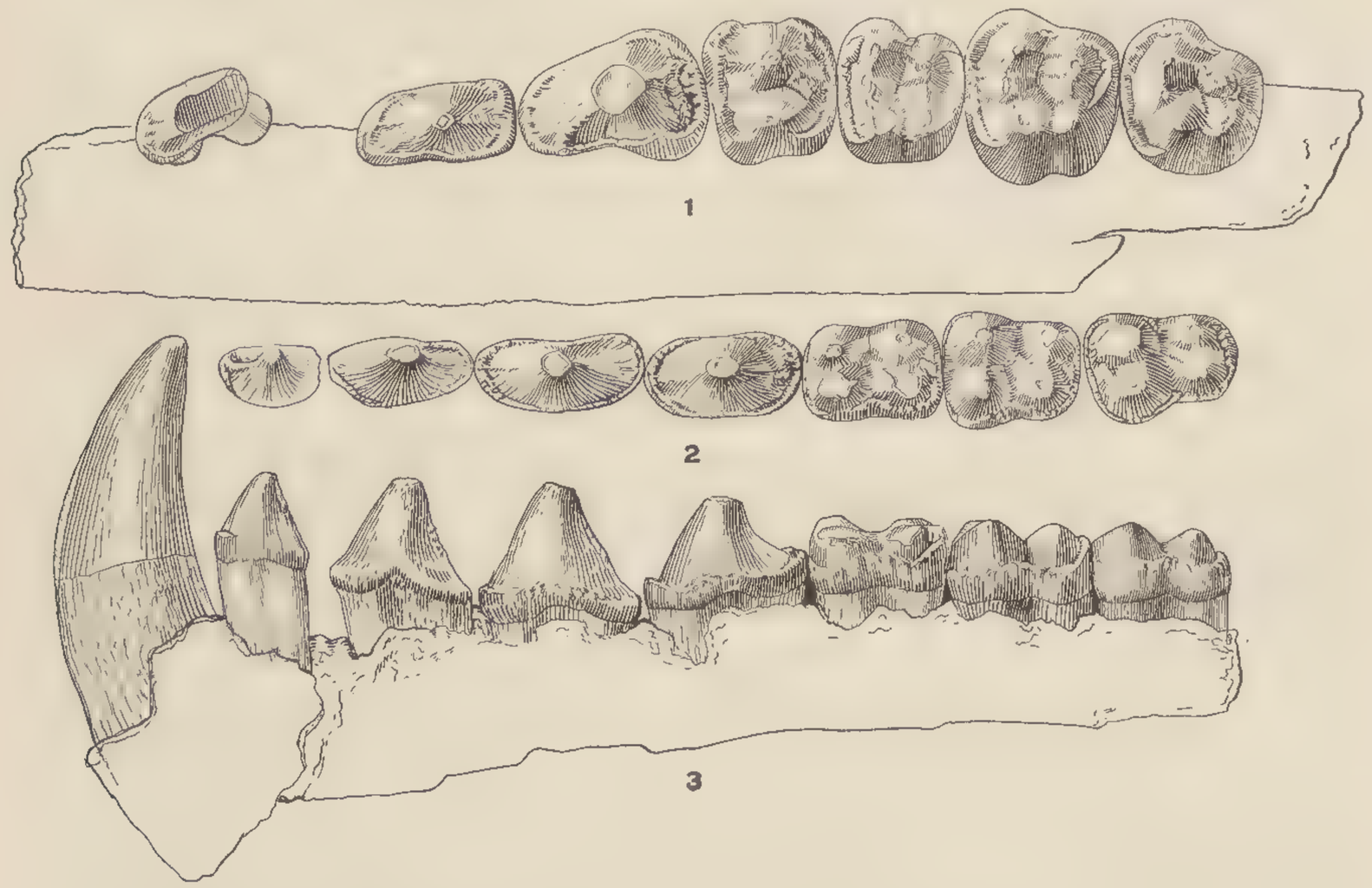


FIG. 1. Type Specimen of *Entelodon magnum* Aymard. ½ nat. size. (1) Crown View of Upper Dentition. (2) Crown View of Lower Dentition. (3) External View of Lower Dentition. (Drawn by Sidney Prentice from Casts of the Original, compared with the Figures given by Kowalevsky.)

than in the American form; para- and metaconids completely united showing no evidence of separations as in young and unworn teeth of *Archæotherium*. The general appearance of the dentition of *Entelodon magnum* seems to point toward a more specialized type, which either represents a later or a more advanced form, so far as the dentition is concerned, than *Archæotherium* from the lower Oligocene of America. Occipital condyle of proportionally great vertical diameter; supra-occipital greatly expanded superiorly and much contracted immediately above the condyles; paroccipital process far in advance of the condyles, relatively compressed antero-posteriorly, and expanded transversely; no evidence of the external auditory meatus immediately in front of the paroccipital process as in *Archæotherium*.

If Kowalevsky's observations[5] regarding the union of the foramen ovale and lacerum medius, as in the recent *Suidæ*, is correct, this is of considerable importance,

[5] Professor Scott (87, p. 284) seems inclined to doubt Kowalevsky's statement that "foramen ovale . . . mit dem foramen lacerum medium versmolzen war, wie bei den heutigen Suidæ und bei Hippopotamus."

since all the known American forms have the foramen ovale separate. In the European genus the manus is relatively low and broad; the magnum and unciform articulate by facets at the dorsal borders; the fibula is free; and the tarsus is low and broad.

Entelodon magnum Aymard.

Type: Fragments of skull, lower jaws, vertebræ, and femur.

Horizon: Oligocene of Ronzon, near Puy-en-Velay, Department of Haute-Loire, Southern France.

Location of Type: Museum National d'Histoire Naturelle, Paris, France.

Two or more specimens were used by Aymard in his original description (**1**, pp. 227–242), and Entelodon is characterized by him as follows:

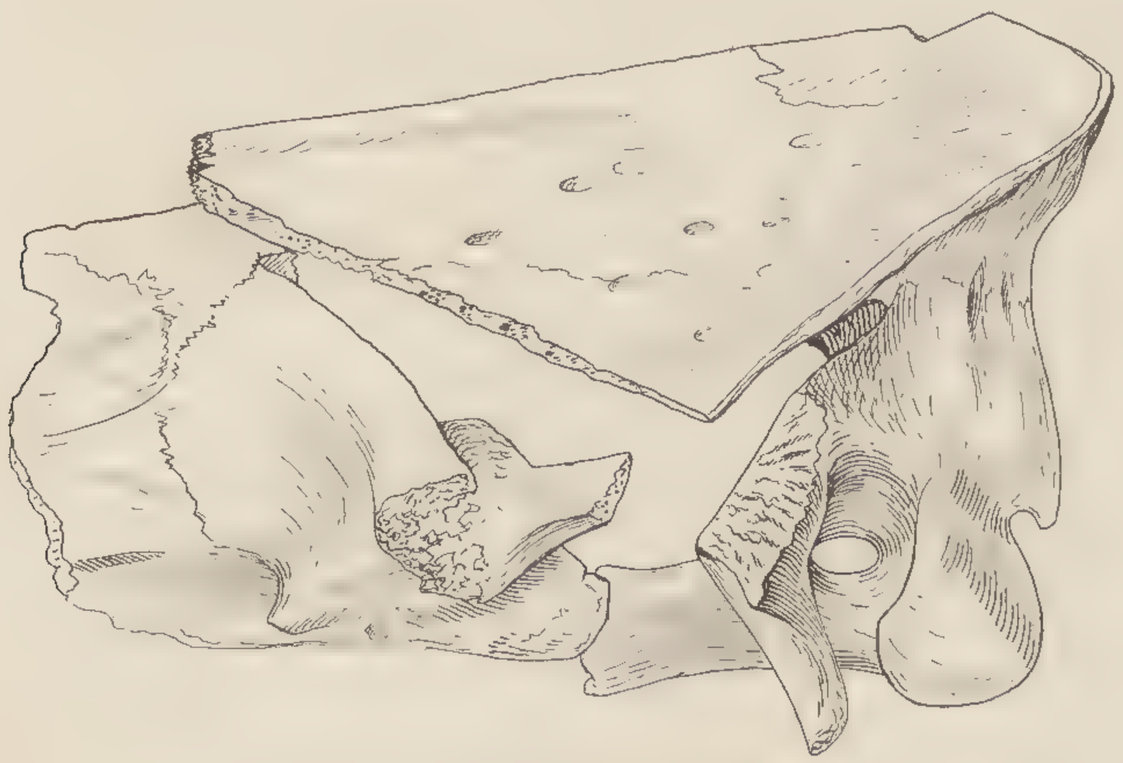


FIG. 2. Lateral View of Skull of *Entelodon magnum* Aymard. ½ nat. size. (After Kowalevsky.)

"Le système dentaire ordonné comme il suit: $\frac{3+1+7}{3+1+7}$ dont $\frac{3+1+3}{3+1+3}$.

"Toutes les dents plus ou moins marquées de fortes stries ou dentelures aux arêtes longitudinales; à collet cernant en partie la base de toutes les molaires inférieures, entourant également en partie les trois premières supérieures, très développé au côté antérieur et au côté postérieur de la molaire principale et des trois arrière-molairs d'en-haut.

"Les incisives d'en-bas subtriangulaires, peu déclives, subterminales, contiguës entre elles et à la canine, et augmentant, en grandeur, de la première a la troisième; les supérieures en cône subtriangulaire, assez épais avec un collet au bord interne.

"Les canines, peu arquées, se déversant peu en dehors; la supérieure moins forte que l'inférieure.

"Les trois avant-molaires, en haut et en bas, coniques, déprimées, portées sur deux racines d'autant plus serées que le dent est plus rapprochée de la canine. La première inférieure à peu pres uniradiculée ; la première supérieure se détachant des suivantes par une petite barre ; la troisième étroite [surtout celle d'en haut] relativement à son analogue des genres voisins, et s'élevant fort au-dessus de la série.

FIG. 3. Posterior View of Skull of *Entelodon magnum* Aymard. ½ nat. size. (Drawn by Sidney Prentice after the Figure given by Kowalevsky.)

"La molaire principale inférieure à couronne conique, simple, élargie en arrière. Celle d'en-haut formant une colline transverse à deux pointes, l'interne assez forte.

"Les trois dernières mâchelières divisées en deux collines transverses, chaque colline ayant trois pointes mousses à la mâchoire d'en-haut et deux à celle d'en-bas. Les supérieures de figure trapézoïde, la pénultième plus forte que la dernière. Celles d'en-bas plus longues que larges ; la dernière dépourvue de talon ou troisième colline.

"La première dentition de la mâchoire inférieure ainsi composée : trois incisives ayant même disposition qu'à la mandibule d'adulte, et à peu près même structure, sauf une épaisseur moins forte de la couronne ; une canine de même forme que les incisives, mais plus haute et plus pointue ; quatre molaires, la première uniradiculée, la seconde à deux racines, la troisième remarquable par la simplicité de sa couronne unicuspidée, et la dernière à trois paires de cônes mousses.

" Le système digital probablement paridigité.

Entelodon ronzonii Aymard.

Type: Isolated teeth.

Horizon: Oligocene of Ronzon, Department of Haut-Loire, Southern France.

Location of Type: Museum National d'Histoire Naturelle, Paris, France.

Aymard established this species on isolated teeth. His description is based principally on the smaller size of the teeth, a lower crown, and greater width posteriorly of $M_{\bar{3}}$, than in his *Entelodon magnum*. Aymard's original description (**1**, p. 22) in full is as follows :

" Nous avons recueilli des dents isolées qui sembleraient indiquer une espèce d'entélodon plus petite que la précédente. Une troisième molaire inférieure, très bien conservée, présente, outre le collet et les arêtes dentelées caractéristiques du

genre, une hauteur proportionnellement moindre de la couronne, et une plus grande largeur en arrière. Elle a, de plus, en avant et en arrière, des plis d'émail et des rugosités distinctifs. Si des découvertes ultérieures de pièces dentaires plus complètes venaient confirmir la valeur de ces caractères, on pourrait imposer à cette nouvelle espèce l'appellation d'*entelodon Ronzonii*, de la colline où sont enfouies ses dépouilles."

Genus ARCHÆOTHERIUM Leidy.

In 1850 Dr. Leidy published a description of the first American forms of the family *Entelodontidæ* under the name *Archæotherium mortoni* (**40,** pp. 93–94). Material of this genus which was subsequently collected from time to time by the early expeditions to the bad-lands of South Dakota and Nebraska was submitted to Dr. Leidy for study and was published by him in different publications under the generic names *Arctodon* (**41,** p. 278), *Entelodon* (**45,** p. 392), and *Archæotherium*. In 1857 (**48,** p. 175) Leidy recognized Pomel's name *Elotherium*, which he continued to use for the American forms in different publications, including his work "The Extinct Mammalian Fauna of Dakota and Nebraska." On Plate IX, figs. 3 and 4, in "The Ancient Fauna of Nebraska" are illustrations representing a fragment of a skull which agrees quite perfectly with Leidy's original description (**40,** pp. 92–93) and is undoubtedly that of the type. Other specimens figured and determined by Leidy as *Archæotherium mortoni* agree with a number of skulls, portions of skulls, and teeth in the Carnegie Museum, which were collected by the writer and others in the *Titanotherium* beds of the same general locality (Nebraska and South Dakota). The Oligocene of North America has yielded much material representing this genus, which is now scattered through the museums of America and Europe.

Principal Generic Characters of Archæotherium: $P\frac{4}{4}$ of relatively small size, with small internal tubercle; the crown triangular in outline; $P\frac{1}{1}$, $\frac{2}{2}$, $\frac{3}{3}$ separated by diastemata; lower molars with the anterior much higher than the posterior tubercles and separated by broad cross-valleys; $P_{\overline{1}}$ separated from canine and $P_{\overline{2}}$ by diastemata; occipital condyles of proportionally small vertical diameter and no accessory facets on the basioccipital; foramen ovale separated from foramen lacerum; dependent processes on the jugal and the inferior border of the mandible; long alveolar border of the premaxillary and a long chin; limbs and feet proportionally long and slender; trapezium present; magnum and unciform articulating slightly with one another at the dorsal border; fibula free.

Archæotherium mortoni Leidy.

Type: A fragment of a skull with $P\frac{3}{3}$ and $P\frac{4}{4}$ in place, and the alveolus for $M\frac{1}{1}$.

Horizon: Oligocene (Titanotherium beds).

Locality: White River, South Dakota?

Locality of Type: Academy of Natural Science, Philadelphia.[6]

Principal characters of Archæotherium mortoni: The first and second incisors of this species are relatively large. The whole series is well spaced in both upper and lower jaws, which is due to the proportionally long alveolar border of the pre-

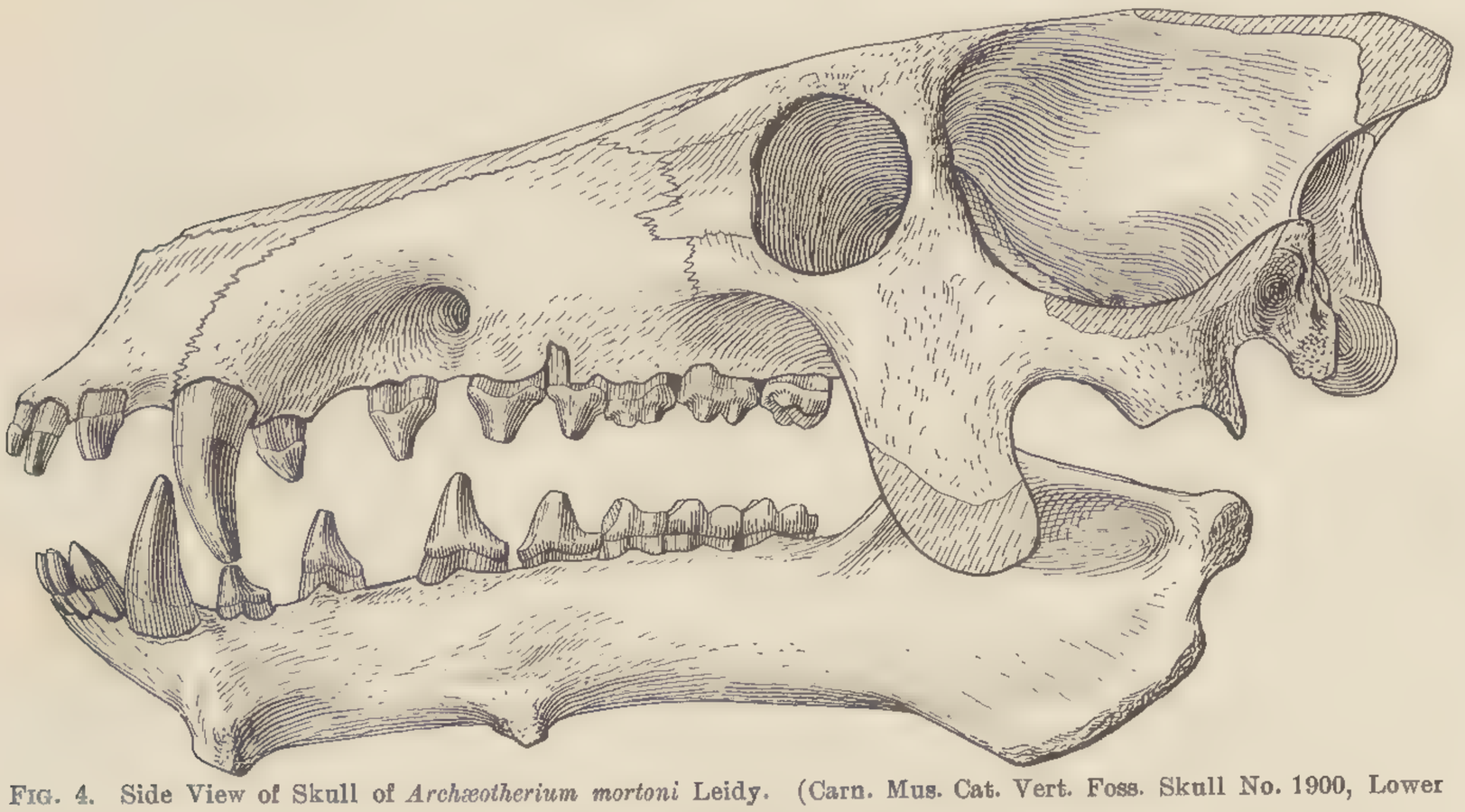


FIG. 4. Side View of Skull of *Archæotherium mortoni* Leidy. (Carn. Mus. Cat. Vert. Foss. Skull No. 1900, Lower Jaw No. 2097.) $\frac{1}{3}$ nat. size.

maxillary and the long chin of the lower jaw. The canines are long and pointed, the premolars are compressed transversely and have comparatively high and pointed crowns. $M^{\frac{3}{3}}$ has small posterior tubercles. The lower molars have proportionally higher and more developed proto- and metaconids, low and little developed hypo- and entoconids and broad cross-valleys. The posterior process of the jugal is com-

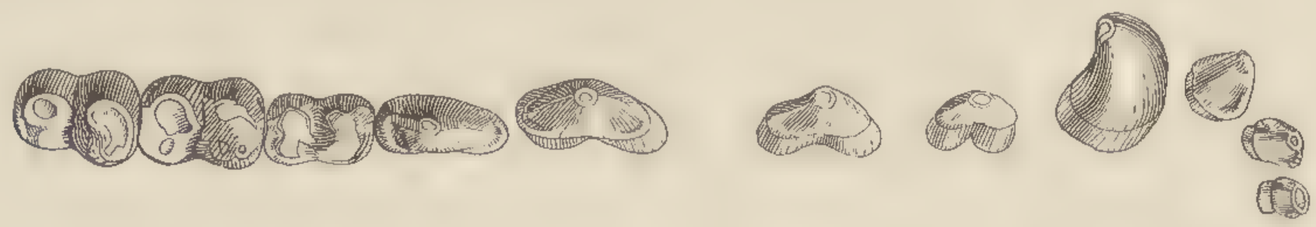


FIG. 5. Crown View of Left Inferior Dentition of *A. mortoni* Leidy. (Carn. Mus. Cat. Vert. Foss. No. 2097.) $\frac{1}{3}$ nat. size.

paratively lightly developed and does not form a buttress on the anterior margin of the glenoid cavity, as in some of the later genera. The anterior protuberances of the inferior margin of the lower jaws are slightly more developed than those further back. The skull represents a comparatively small-sized animal. A specimen,

[6] The specimen at this writing has no catalog number.

fragments of skull and lower jaws (No. 2011, Carnegie Museum Cat. Foss. Vert.), was collected in the Oreodon beds near Dickinson in the Little Bad-lands of North Dakota by Earl Douglass. This has the entoconid of $M_{\overline{3}}$ well represented, the anterior tubercles of the lower molars very high, as in *A. coarctatum*, the premolars rather small, but $P_{\overline{3}}$ separated from $P_{\overline{4}}$ by a diastema as in *A. mortoni*. The upper molars are relatively longer and narrower than those in the typical specimens of *A.*

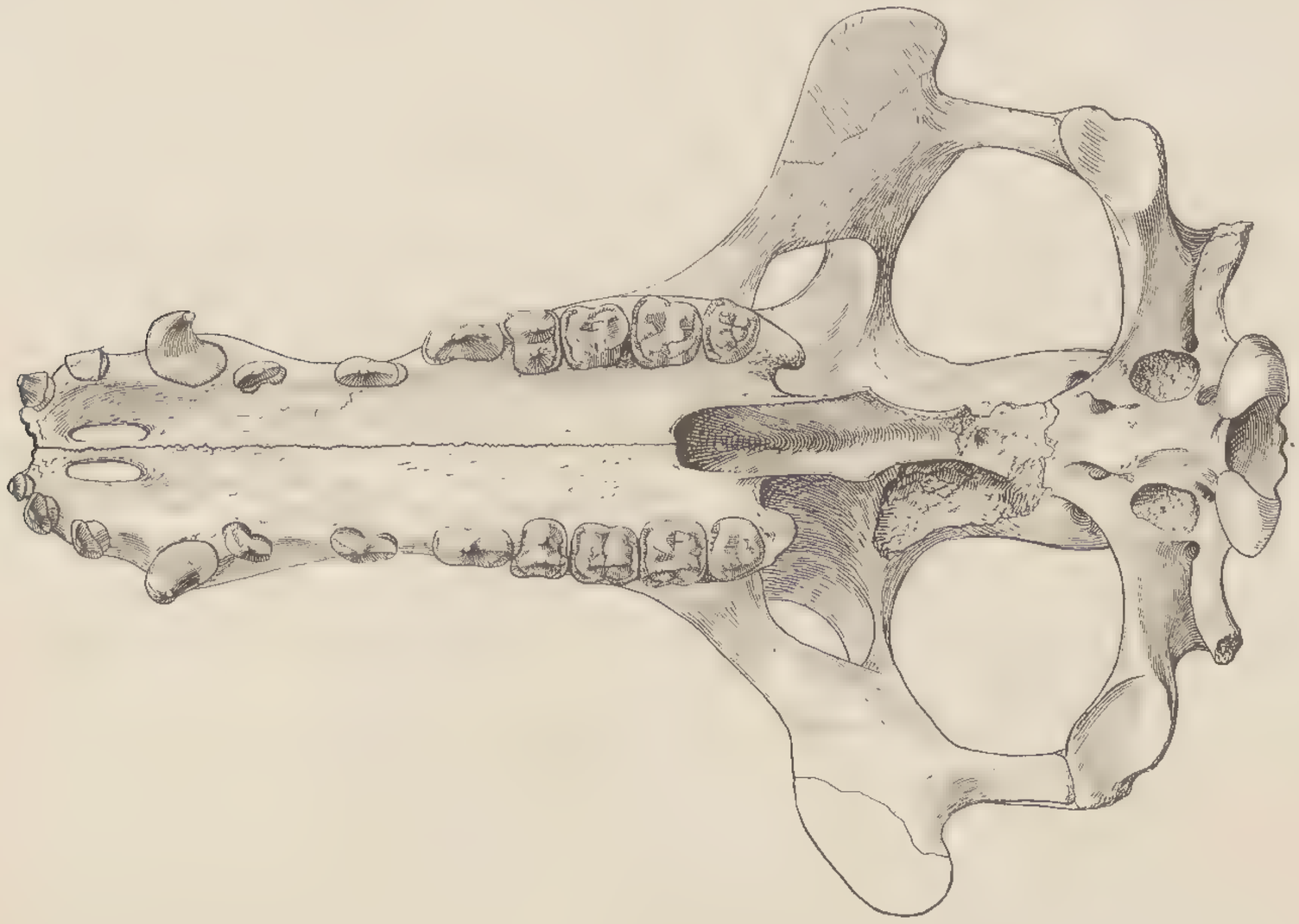


FIG. 6. Palatal View of Cranium of *Archæotherium mortoni* Leidy. $\frac{1}{8}$ nat. size. (Carn. Mus. Cat. Vert. Foss. No. 1900.) The oblong area in front of the condyle represents the broken tympanic bullæ.

mortoni. This would seem to indicate that there is a considerable range of individual variation in the species *A. mortoni*.

Archæotherium mortoni subsp. **clavum** (Marsh).

Type: Skull.

Horizon: Lower Oligocene (Titanotherium beds).

Locality: Bad-lands of South Dakota.

Locality of Type: In Collection of Yale Museum, No. 2035.

The type of this subspecies is the skull of an animal the size of *Archæotherium mortoni*, and the characters which Professor Marsh has given do not clearly distinguish it from the latter species. Marsh states that the skull agrees in many respects

with that of *A. crassum*, but is smaller, "the malar process is quite slender and tapering below [and] extending downward. . . . The dentition agrees in the main with that of *E.* [*A.*] *crassum*, the last lower molar in each having four cones only, and no heel." The malar arch and the dependent angle of the lower jaw, which Professor Marsh states, "will distinguish it from *A. mortoni*," are found to be present and more or less developed in all the specimens of this family found in America with these parts preserved.

In my notes on the type of *Archæotherium clavum* taken in the Yale Museum I find the following statements, which tend to show that Marsh's species should at least be given a subspecific rank:

"The general contour of the skull is much the same as that of *A. crassum*, the occiput is not overhanging, the anterior border of the orbit is opposite the middle portion of $M\frac{2}{-}$, the antorbital foramen is large and placed over $P\frac{3}{-}$. Premaxillaries produced forward giving plenty of room for the incisors, which are separated by

FIG. 7. Skull of *Archæotherium clavum* Marsh. About $\frac{1}{5}$ nat. size. (After Marsh.)

diastemata except $I\frac{1}{-}$ and $I\frac{2}{-}$. The latter are, however, well separated at the apices. The orbit is placed slightly higher than in *A. crassum*. The dependent broad process of the jugal is not large, and, as Marsh stated, points directly downward and also slightly outward. The zygomatic process perhaps did not reach to the anterior border of the glenoid cavity. The condyles are well separated superiorly and inferiorly and the paroccipital process is rather short and truncated. The foramen magnum is large and subtriangular in outline. The chin has a considerable slope and is quite convex from side to side. The anterior knob-like protuberances are not large and are placed well back as in some species from the John Day formation. The posterior protuberance has the same relative size as in *A. crassum*. The anterior mental foramen is rather small and is placed low down on the mandible, opposite the anterior face of $P_{\overline{1}}$. The posterior mental foramen is higher up upon the mandible and is opposite the posterior face of $P_{\overline{2}}$.

"$I\frac{1}{1}$ relatively large, upper canines much elongated and pointed, $M\frac{1}{1}$ with well developed cingulum externally, $M\frac{2}{2}$ with cingulum faintly developed externally, and $M\frac{3}{3}$ with cingulum developed only on the antero-external angle. Lower canine rather short, which may be due to the fact that the specimen pertains to a rather young, though adult individual. Lower premolars high and sharply pointed; molars with high anterior tubercles. $M_{\overline{3}}$ with an unusually prominent posterior basal heel.[7] Cingulum only fairly indicated on the external faces of the inferior molars."

Archæotherium crassum (Marsh).

Type: Fragments of a skeleton.

Locality: Eastern Colorado.

Horizon: Lower Oligocene (Titanotherium beds).

Locality of Type: In Collection of Yale Museum, No. 12020.

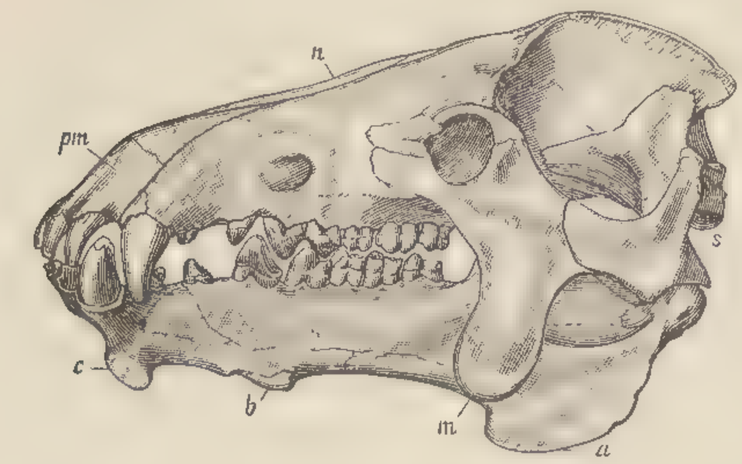
In 1873 Professor Marsh founded this species on fragments of a skeleton (**58a,** p. 487). It was apparently the first time that the characteristic dependent process of the jugal of the American forms of the *Entelodontidæ* had been observed, and Marsh compared this process with those on the zygomatic arch in some Edentates and Marsupials. Marsh also pointed out that the radius and ulna of this species were separated or very loosely united.[8] Some idea of the foot structure of this species was also derived from this specimen. In a later paper (**63,** p. 408) Marsh more fully describes the type, together with additional material collected in Colorado, South Dakota, and Nebraska. On Plate VIII of this publication Marsh figures the skull and feet, which he regards as belonging to *A. crassum*, and states that the dependent process of the jugal "extends downward to the inferior margin of the lower jaw in front of the angle. This is the case when these processes are somewhat expanded transversely, as shown in figures 2 and 3, which represent the skull as it lay in the matrix" (see fig. 8). Marsh also calls attention to the small brains, the structure of the feet, and to the protuberances on the inferior border of the lower jaw, of which the anterior pair is slightly the heavier. In 1894 Marsh published the restoration of *A. crassum* (**64,** pp. 407–408, Pl. IX) and finally in 1897 published the same restoration (**65,** Pl. XXX) with the legend *Entelodon crassus*. In the text of the same volume, pp. 522–523, Marsh also referred to *Archæotherium* as *Entelodon*.[9] Through the courtesy of Professors Schuchert and Lull of Yale University the pres-

[7] The posterior position of the chin-process, the high anterior tubercles of the lower molars, and the prominent basal heel of $M_{\overline{3}}$ are among the more important characters of this subspecies.

[8] This is probably true of nearly all the species from the lower beds.

[9] This indicates that Marsh had already obtained some information which led to Miss Lucy P. Bush's publication of a later date in the American Journal of Science (Series IV, Vol. XVI, pp. 97–98, 1903).

ent writer was recently able to carefully study the type and the other material referred to *A. crassum* by Marsh. My observations are of some interest in this connection, as they serve to further characterize this species. I at once detected that the premaxillaries are long, as is usual in the species from the lower Oligocene, the preorbital foramen is above P– and is of large size, the orbit is rather low, and has the anterior border opposite the posterior part of $M^{\frac{2}{2}}$. The downward projecting process of the jugal is directed rather more forward than backward and terminates in an enlarged and somewhat oval free end; the zygomatic process does not quite reach the anterior border of the glenoid cavity. $P_{\frac{3}{3}}$ has a characteristically limited antero-posterior diameter. $P_{\frac{1}{1}}$ and $P_{\frac{2}{2}}$ are abruptly reduced as in *A. coarctatum* Cope, and the anterior tubercles of the molars are quite high, as in that species. The superior molars are yet buried in the matrix, so that nothing more can be said regarding their characters, than that they have apparently anterior and posterior cingula, as usual, but are externally almost smooth.



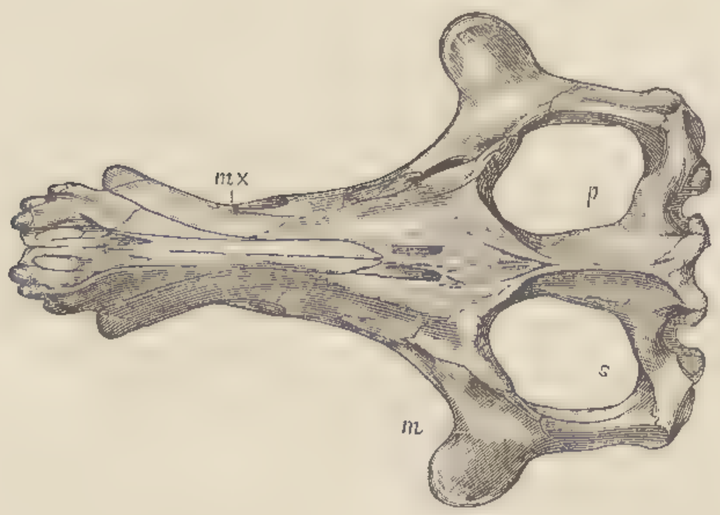


FIG. 8. Side and Upper View of Skull of *Archæotherium crassum* Marsh. $\frac{1}{8}$ nat. size. (After Marsh.)

There are only a few fragments of vertebræ with the type. Portions of left arches of two dorsal vertebræ show perforations of large foramina at the base of, and immediately posterior to, the transverse processes, but in neither of the two arches are there any indications of vertical canals as in *Dinohyus*.

The limbs of the type specimen are very fragmentary; there is no scapula. The great trochanter of the humerus is very prominent and terminates superiorly above the head in an enlarged and truncated end, directed backward and with the process of the lesser tuberosity nearly enclosing the bicipital groove. The intertrochlear ridge is prominent and the external condyle is narrow. The internal epicondyle is relatively prominent. The calcaneal facet of the cuboid is broader than that for the astragalus. Mt. IV is complete and measures 155 mm in length. Mt. V was of relatively large size, judging from the facet for it on Mt. IV. The metapodial as a whole is rather delicate and the cross-section of the upper half of the shaft has a square appearance.

In the Carnegie Museum is a good portion of a skeleton with the vertebral column well represented, but without the skull or jaws (No. 1665, Carn. Mus. Cat. Vert. Foss.), collected by the writer in the *Titanotherium* beds on Sand Creek, Sioux County, Nebraska. This specimen has the sides of the walls of the neural arches perforated in a manner similar to that of the type of *A. crassum*. The specimen pertained to a somewhat larger individual than the type in the Yale Museum, but it is here referred to *Archæotherium crassum*. A skull and four cervical vertebræ (Carn. Mus. Cat. Vert. Foss. No. 142) which are referred to *A. crassum*, were collected by Mr. J. B. Hatcher in 1900, near the base of the Titanotherium beds on Lance Creek, Converse County, Wyoming. The skull of this specimen is much depressed by crushing, but is of interest because it supplies characters which show a considerable range of individual variation in this species. While the skull is of about the same proportionate size as that of *A. crassum* in the Yale Museum, it is seen that the dependent process of the jugal is of much smaller size and shorter, the superior border of the orbit is higher[10] or more nearly even with the transverse face of the frontals, the antorbital foramen is slightly further forward, and the cingula of the teeth are more strongly developed than in the specimen in the Yale Museum.

Archæotherium ingens (Leidy).

Types: Symphysis of lower jaws without teeth, the crown of an inferior molar, and several mutilated canine teeth.

Horizon: Oligocene (Upper Titanotherium beds?).

Locality: Nebraska (White River?).

Locality of Types: Unknown to the writer.[11]

The figures 8–11, which Professor Leidy gives on Pl. XXVII in "The Extinct Mammalian Fauna of Dakota and Nebraska," seem to agree with his original description of "*Entelodon ingens*" (**47,** pp. 164–165) and are undoubtedly to be regarded as the types of that species, although Leidy does not make this clear. The species was originally separated wholly on account of its greater size. On pages 192–194 (Ext. Mam. Fauna) Leidy gives a list with measurements of specimens, which he regarded as pertaining to *A. ingens*, but with no adequate description. To Professor W. B. Scott of Princeton University we are indebted for an admirable Memoir (**87,** pp. 273–324), the descriptions in which are based on a very nearly complete skeleton (Princeton Museum Collection No. 10885) collected in the upper Titanotherium beds of South Dakota by the late Mr. J. B. Hatcher and regarded by

[10] Even when the crushing of the skull is taken into proper consideration this character is especially noticeable.

[11] In the Proc. Acad. Nat. Sci. Philad., Vol. VIII, p. 165, 1856, Professor Leidy states that the specimens were collected by Dr. Hayden for the St. Louis Academy of Sciences.

Scott as "*Elotherium ingens.*" Scott states (**87,** p. 274) that the upper incisors "increase regularly in size from the first to the third, the latter being much the largest of the series; it has a conical or somewhat trihedral crown and resembles a canine

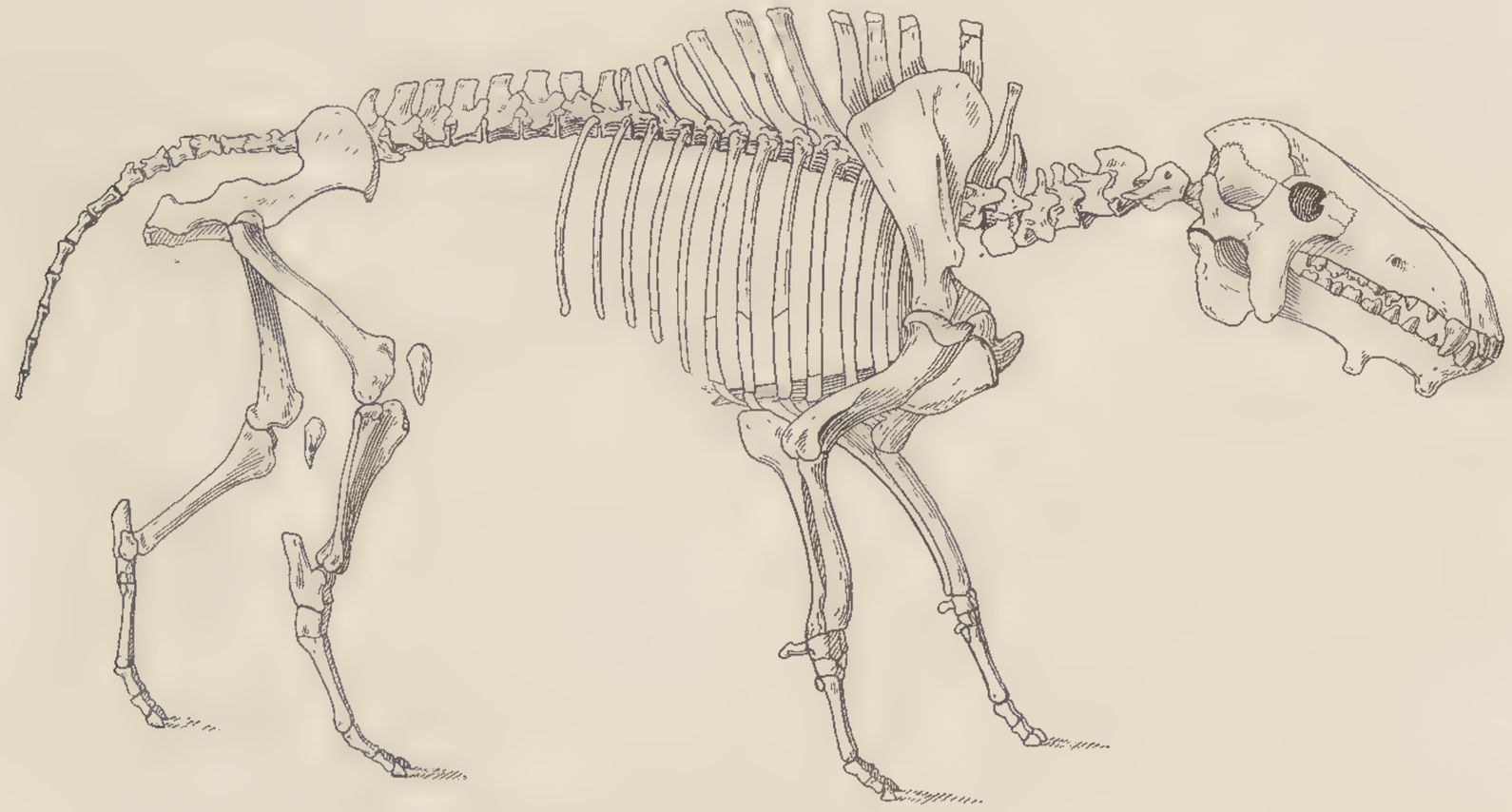


FIG. 9. Restoration of Skeleton of *A. ingens* Leidy. About $\frac{1}{18}$ nat. size. (After Scott.)

in shape and appearance. . . . The other incisors have spatulate crowns, with blunted tips, the attrition of use wearing down the apices as well as the posterior faces of these teeth. This description applies more particularly to the larger White River species, such as *E. ingens* and *E. imperator*; in *E. mortoni* the upper incisors are of more nearly equal size and more conical shape." In speaking of the upper premolars the same author states (*l. c.*, p. 275): "In the smaller species of the genus such as *E. mortoni*, $P\frac{3}{}$ and $P\frac{4}{}$ are placed close together, while in the larger forms these teeth are separated by a short space and the diastemata between the other premolars and between $P\frac{1}{}$ and the canine are relatively somewhat greater, the enlargement of these teeth hardly keeping pace with the elongation of the muzzle." The general contour of the skull in *E. ingens* is somewhat different from other species especially those from the lower beds. Thus, Scott (*l. c.*, p. 280) states: "In most American species the forehead rises very gradually and gently behind to the sagittal crest, but in *E. ingens* the rise is much more sudden and steep." The dependent process of the jugal "descends from beneath the orbit downward and outward to below the level of the ventral border of the mandible [and] forms a club-like thickening at the tip, which . . . is coarsely crenulate on the posterior border. . . . In *E. ingens*,

from the Titanotherium beds, these openings [supraorbital foramina] are of good size, are placed quite near to the median line, and have well-marked vascular channels running forward from them." On the ventral border of the mandible the knob-like processes are well developed. In the type represented in Fig. 10, Pl. XXVII (Ext. Mam. Fauna of Dakota and Nebraska) these processes are shown to be of quite large size. In the dorsal vertebræ of the specimen, which Professor Scott referred to *E. ingens*, the canals perforating the walls of the neural arch for the spinal nerves are small and quite irregular in their position, indicating that they had a less important function than was the case in *Dinohyus* and *Sus*. The trapezium (tm. in fig. 10) is present in the manus of the splendidly preserved specimen in the Princeton Museum.

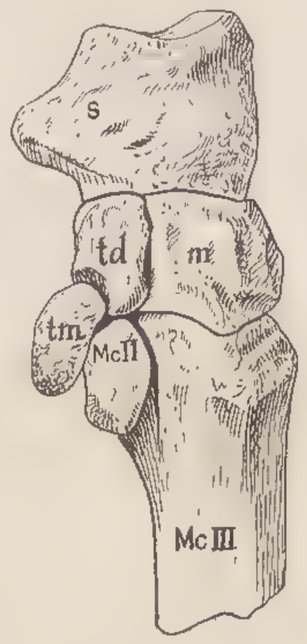


FIG. 10. Inside View of Carpus of *A. ingens* Leidy, showing Trapezium in Position. ½ nat. size. (Princeton Mus. Cat., No. 10885.)

Archæotherium coarctatum (Cope).

Type: A left mandibular ramus with molar-premolar series complete.

Horizon: Lower Oligocene, Titanotherium beds?

Locality: Cypress Hills, District of Assiniboia, Canada.

Locality of Type: Collection of the Geological Survey of Canada, Ottawa.[12]

The name *Entelodon mortoni* was used by Professor Cope in his first report of the presence of remains of the *Entelodontidæ* in Canada (**17a,** p. 163). Later he referred this material to "*Elotherium*" *coarctatum*, which again was changed by him in 1891 (**23,** p. 20) to "*Elotherium arctatum.*" The type as figured on Plate XIV (**23**) clearly indicates this species as valid and the more important characters may be quoted from Professor Cope's description: "The species differs from *E. mortoni*, with which it agrees nearly in size, in having all the premolars in a series uninterrupted by diastemata except a very short one between Pm. III and IV [$P_{\bar{2}}$ and $P_{\bar{1}}$].[13a] The second premolar [$P_{\bar{3}}$] [13a] is the most elevated, and the third and fourth [$P_{\bar{2}}$ and $P_{\bar{1}}$][13a] are abruptly smaller. The fourth [$P_{\bar{1}}$] [13a] has one [13] compressed grooved root. . . . The posterior, or fifth tubercle is well developed, especially on the M. III [$M_{\bar{3}}$]." [13a] (See crown view in fig. 11.)

[12] Without catalog number.

[13] From the illustration it would appear that there were probably two roots on $P_{\bar{1}}$, perhaps coalesced near the crown which is usual in many species from higher horizons.

[13a] The notation of the teeth enclosed in brackets [ ] is given by the writer, in order to facilitate the understanding of Prof. Cope's description, in which he used the now obsolete method of numbering the teeth from the back of the jaw forward.

Professor Cope points out the "close-placed premolar teeth" and the elevation of the anterior tubercles[14] of the true molars as a more primitive character than is displayed by any of the American species so far known. To this may also be added the abrupt reduction of $P_{\overline{2}}$, which, though distinctly smaller than in *A. mortoni*, is, however, again repeated in *Dinohyus* from the Miocene. The latter has $P_{\overline{1}}$ and $P_{\overline{2}}$ of very nearly the same relative size as in *Archæotherium coarctatum*. The

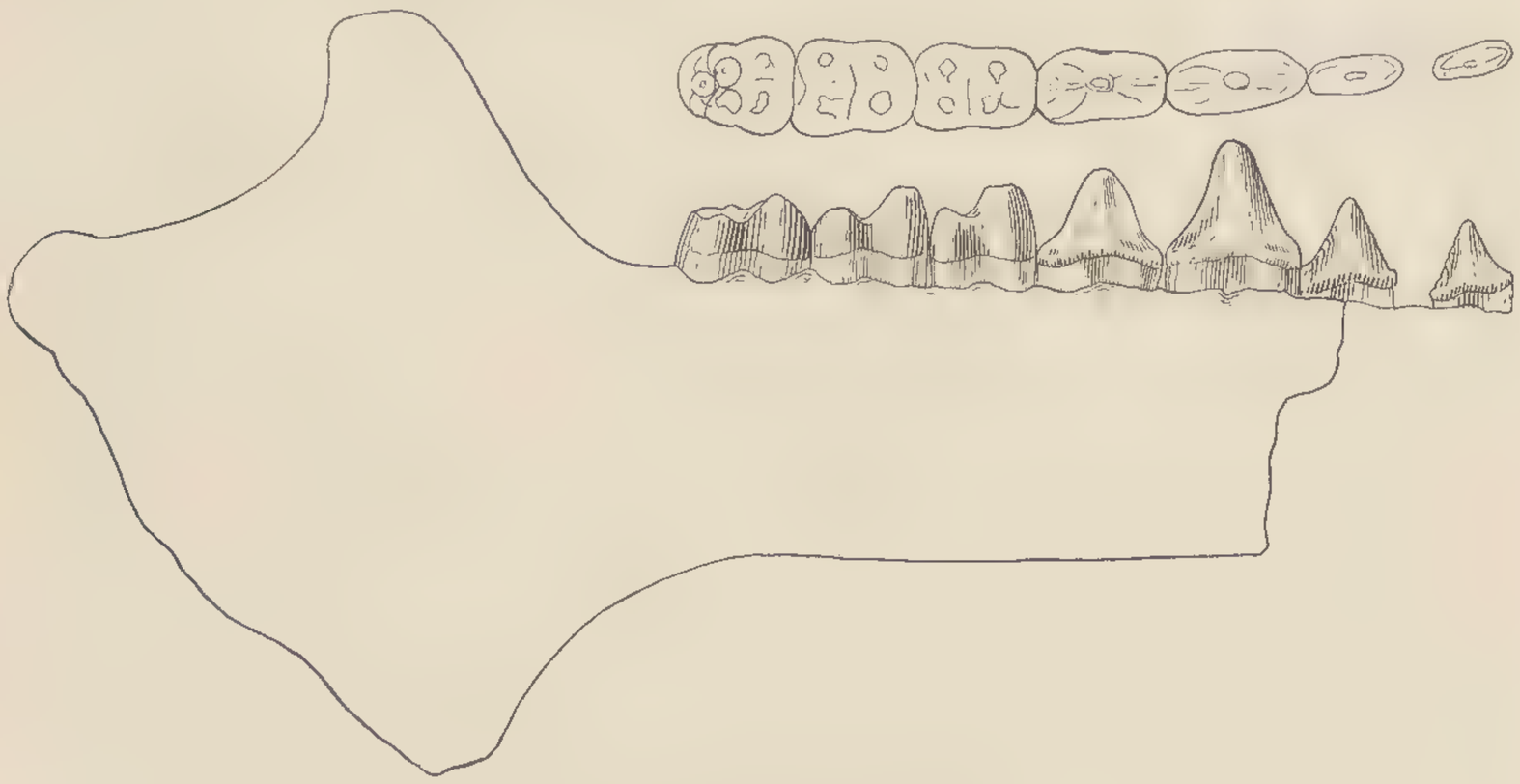


FIG. 11. Type of *Archæotherium coarctatum* Cope. About ½ nat. size. (After Cope.)

development of the posterior tubercles on $M_{\overline{3}}$ of the latter species seems to indicate a slight advance in modification toward the later forms, *Dinohyus* and *Ammodon*, while in the typical forms of *A. mortoni* these tubercles are less developed.

Subgenus PELONAX Cope.

Pelonax ramosum Cope.

Type: The greater part of a mandible.

Horizon: Upper Oligocene?

Locality: Eastern Colorado.

Locality of Type: The American Museum of Natural History. (Cope Collection, No. 6393.)

In the original description (**7**, p. 27) of the subgenus *Pelonax* Professor Cope enumerates strong specific characters, viz.: the "great size of the tubercles on the under side of the mandibular ramus, especially the anterior pair . . . the first and

[14] It should be carefully borne in mind that all the species known from the lower Oligocene beds have the anterior cusps of the molars higher in a greater or less degree.

second of the four premolars are separated by a diastema and have but a single [16] root . . . the tubercles of the molars are low . . . the last molar two-lobed and rather small," which should be regarded at least as of subgeneric value. Cope erected the genus *Pelonax* in 1874 (**6,** pp. 504–505) and said that it embraces species "nearly allied to *Elotherium*. It is more hippopotamoid than that genus [*Archæotherium*] in the possession of four [17] digits on all the feet and a rudimentary fifth on the pes." The statement regarding the digits of Cope's genus *Pelonax* is misleading,

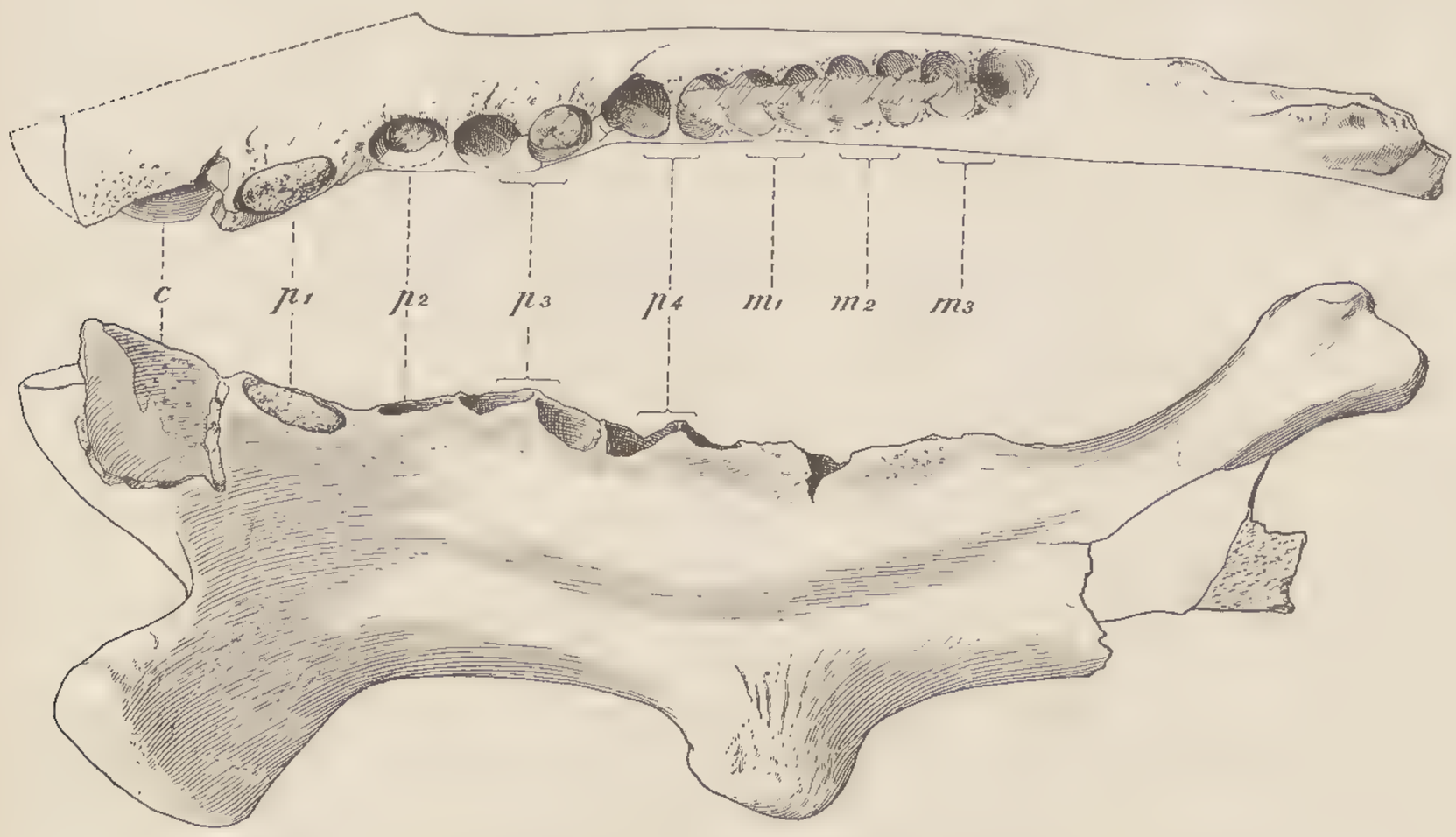


FIG. 12. Type of *Pelonax ramosum* Cope. Cope Collection, No. 6393. About ½ nat. size.

but the very large tuberosities on the chin and the single-rooted premolars, together with the characters enumerated above, are of considerable significance, and may be regarded as characterizing this subgenus. More material representing limbs and vertebræ associated with jaws and skulls from the type locality is of extreme importance in connection with the study of this subgenus.

Pelonax bathrodon (Marsh).

Type: $M_{\overline{3}}$ of right side.

Horizon: Upper Oligocene. Protoceras Sandstones?

[16] In a letter of reply from Dr. Matthew, of the American Museum of Natural History, New York, dated Feb. 26, 1908, I am assured that Cope's statement regarding the single-rooted premolars is correct.

[17] No true Entelodonts from the Oligocene of America or Europe have as yet been found with four digits on all the feet, as in hippopotamus.

Locality: Bad-lands of South Dakota.

Locality of Type: Collection of Yale Museum, No. 12030.

The tooth figured in 1893 by Professor Marsh (**63,** Pl. IX, fig. 4), and referred to the genus *Ammodon,* though inadequate as a type, fortunately shows characters which at once separate it from *Ammodon leidyanum,* not only specifically, but also generically (see fig. 13). In Marsh's original description in 1874 (**59,** p. 534), he gives the principal characters of $M_{\overline{3}}$ of his proposed species "*Elotherium*" *bathrodon,* which constitute the chief differences between that tooth of the latter species and the genus *Ammodon.* Marsh says: "This molar differs essentially from the same

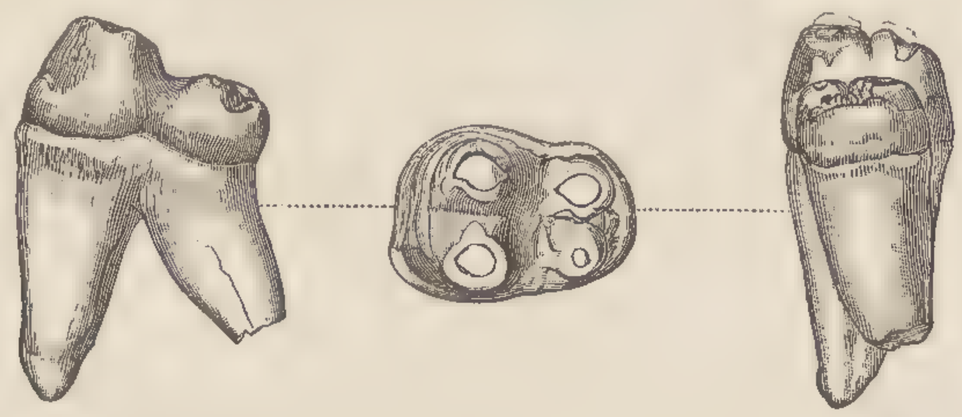


FIG. 13. Last Lower Molar of *P. bathrodon* Marsh. ½ nat. size. (After Marsh.)

tooth in the other known species of this genus [*Elotherium*], especially in having the anterior pair of tubercles much larger than the posterior pair, and elevated high above them."[18] On comparing Marsh's figures reproduced in this connection (fig. 13) it is at once seen that the tubercles are more distinctly separated by narrow longitudinal valleys, and that the cross-valley between the anterior and posterior tubercles is open and very broad, which is due to the small development of the posterior tubercles; a character common to the older American types of the family *Entelodontidæ.* In *Ammodon* and *Dinohyus* the development of the posterior tubercles (ento- and hypoconids) is relatively greater and the cross-valley is very much reduced in the antero-posterior direction. The distinct development of the fifth cone (hypoconid) in *Ammodon leidyanum* seems to have progressed in the same general ratio as that of the posterior tubercles.

In the Yale Museum is a specimen of an Entelodont, which was collected in 1890 by Mr. J. Brown and bears the catalogue number 10008. This specimen is a skull of a large individual apparently from the Protoceras sandstones of the Oligocene. The front and back of this skull is broken off so that its length cannot be ascertained. The size of the molars corresponds quite well with that of the tooth described by Marsh as the type of *Pelonax bathrodon,* and, from the fact that it was

[18] This elevated position of the anterior portion of the crown seems to be greater than in *Pelonax potens.*

found in the upper Oligocene, it would seem quite reasonable to suppose that it belongs to the same species.

The premolars of this skull are rather pointed, with wrinkled enamel, and with comparatively small antero-posterior diameter, approaching *Dinohyus* in these characters. $P^{\underline{4}}$ has a small paracone and a very strong cingulum, which nearly surrounds the tooth; the external face is quite smooth, except the posterior and anterior angles. The molars have distinctly separated tubercles and rather broad or open cross-valleys. Opposite the cross-valley on the internal faces of $M^{\underline{1}}$ and $M^{\underline{2}}$ the heavy rounded cingula, or swellings, which are so prominent in *Dinohyus hollandi*, are indicated. The anterior tubercles of M^3 are well separated, while the posterior tubercles are fused and elevated posteriorly, so as to form a basin of the cross-valley; the tooth as a whole is relatively small when compared with *Dinohyus*.

The frontals are much less inflated than in the type of *Dinohyus*. Judging from the crushed condition of the skull, I am inclined to think that the anterior border of the orbit is opposite the posterior part of $M^{\underline{3}}$, or perhaps somewhat further back. The anterior border of the posterior nares is opposite the posterior part of $M^{\underline{3}}$. The dependent process of the jugal is very broad and extends well down.

A second specimen in the Yale Museum, which may be referred to *Pelonax bathrodon* (No. 10009), is a skull and lower jaws of a rather young individual. This has an unusual development of the posterior basal tubercles (hypoconulids) of the lower molars. The ento- and hypoconids of $M_{\overline{1}}$ and $M_{\overline{2}}$ are also relatively high in comparison with most Entelodonts from the Oligocene, while those of $M_{\overline{3}}$ are low as in the type of *Pelonax bathrodon* and the cross-valley is also broad in the same manner.

MEASUREMENTS.

Skull No. 10008, Yale Museum.

			Mm.
Total length of the skull fragment about			540
Breadth of skull at $M^{\underline{2}}$			144
Antero-posterior diameter of P^2			32
Transverse	"	" P^2	19
"	"	" $P^{\underline{3}}$	28
Antero-posterior	"	" $P^{\underline{3}}$	41.5
"	"	" $P^{\underline{4}}$	31
Transverse	"	" $P^{\underline{4}}$	34
"	"	" $M^{\underline{1}}$	40
Antero-posterior	"	" $M^{\underline{1}}$	38
"	"	" $M^{\underline{2}}$	39.5
Transverse	"	" $M^{\underline{2}}$	43
"	"	" M^3	37
Antero-posterior	"	" $M^{\underline{3}}$	633

Pelonax potens (Marsh).

Type: Greater portion of left ramus and symphysis.

Horizon: Not indicated; most probably upper Oligocene.

Locality: Oligocene of Colorado.

Locality of Type: Collection of Yale Museum, No. 12042.

The most conspicuous feature of this type is the great development of the anterior dependent process of the inferior face of the lower jaw, which, as in *Pelonax ramosum*, gives to the chin an unusually short and rather broad appearance. The alveolus for $P_{\bar{1}}$ indicates that the roots were well[19] coalesced near the crown, a character usually found in types from the upper Oligocene, and which should be regarded as of subgeneric value. The antero-posterior diameter of $P_{\bar{3}}$ must have

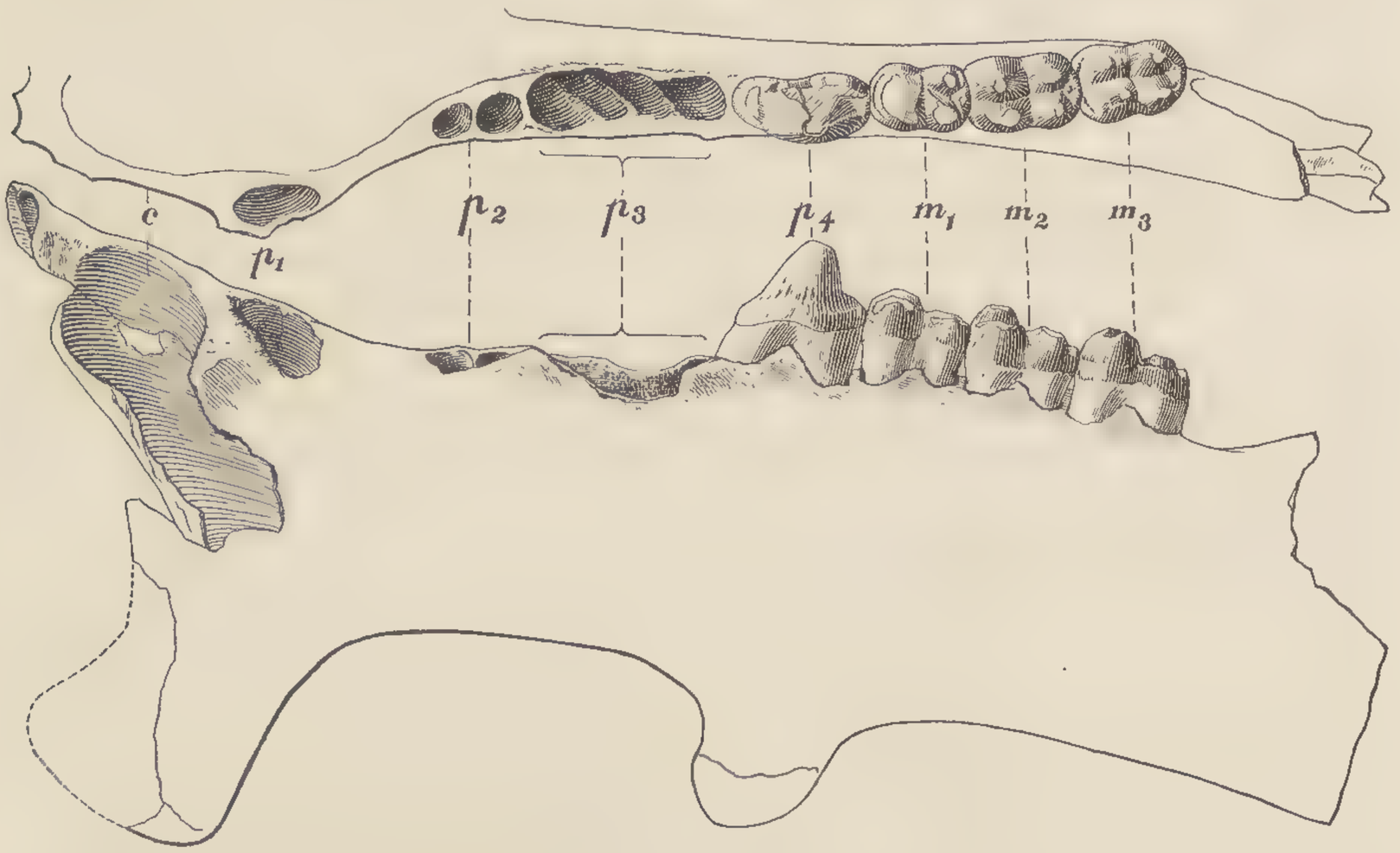


FIG. 14. Type of *P. potens* Marsh. About $\frac{1}{3}$ nat. size. (Yale Museum, No. 12042.)

been quite great, judging from the space which the alveolus occupies. The molars indicate a smaller individual than *Pelonax bathrodon*, as stated by Marsh (**63,** p. 410), but possessing the same characters as the latter, *i. e.*, the anterior tubercles of the molars are higher than the posterior, and the latter separated from the former by broad, transverse valleys. When more complete material from the Oligocene of Colorado is found, the validity of the type of *Pelonax potens* will be more satisfactorily established.

[19] In *Pelonax ramosum* $P_{\bar{1}}$ and $P_{\bar{2}}$ are apparently single-rooted.

Subgenus (?) BOÖCHŒRUS Cope.

Boöchœrus humerosus Cope.

Type: A portion of a skeleton without the skull or teeth.

Horizon: (Upper?) John Day Formation.

Locality: John Day River, Oregon.

Locality of Type: The American Museum of Natural History, Cope Collection, No. 7380.

The genus *Boöchœrus* was proposed by Cope and the type was fully described in 1879 (**10,** pp. 59–66). This John Day form has been regarded as belonging to *Archæotherium* by authors who have occasionally referred to it, and it is even now difficult to correctly place the remains generically, as there are unfortunately no remains of the skull or teeth with the type. The present arrangement must, therefore, be regarded as only provisional, pending the discovery of more material in the typical locality.

After restudying the type, and after comparing it with the splendid skeleton of *Dinohyus hollandi* from the Agate Spring Fossil Quarries, as well as with the Princeton specimen of *Archæotherium ingens* from the Titanotherium beds, which was described by Professor Scott, it appears that there are certain characters of generic value. When the skeleton of *Dæodon* is thoroughly known, *Boöchœrus* may possibly have to be referred to that genus.

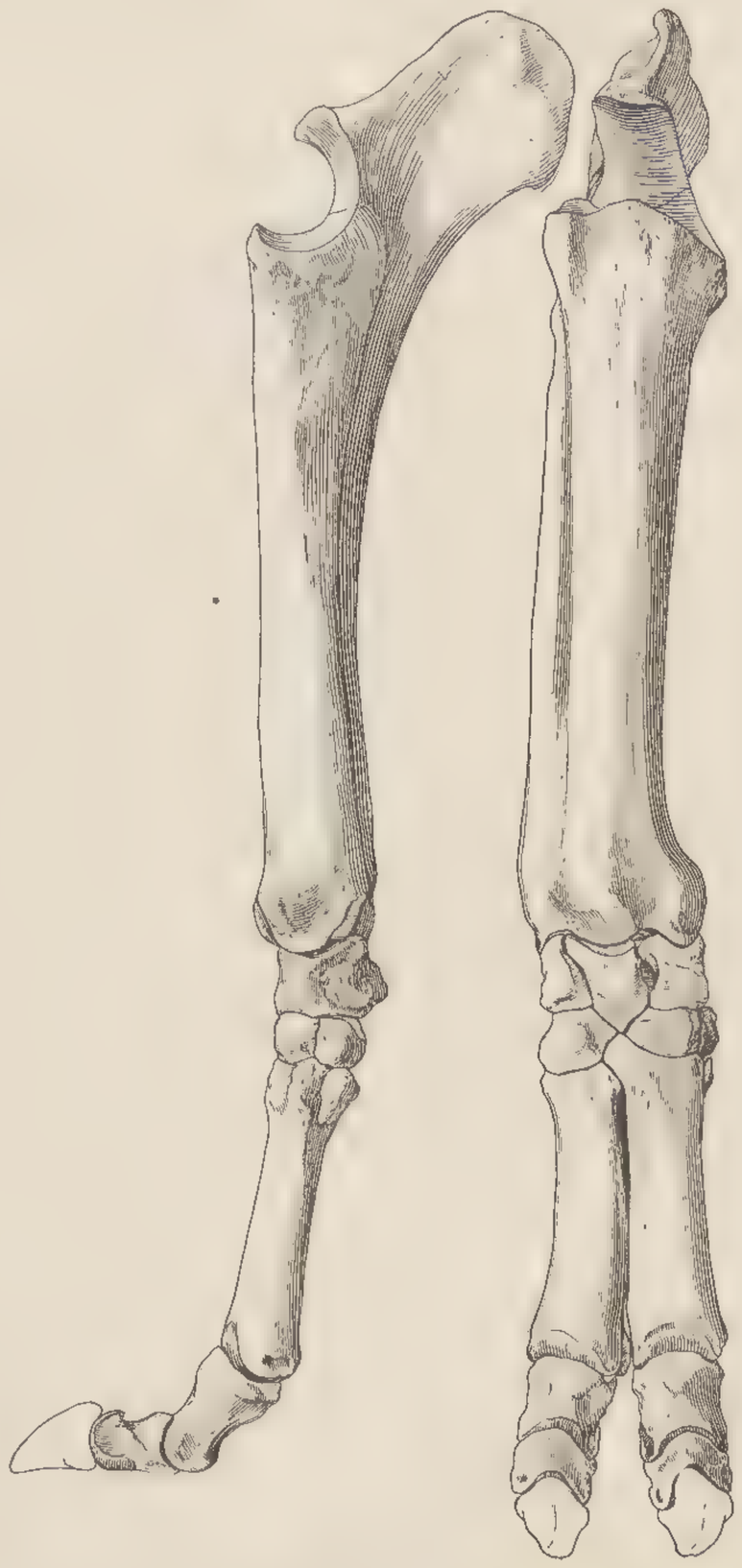


FIG. 15. Front and Inside View of Right Forefoot of *B. humerosus* Cope. About $\frac{1}{8}$ nat. size. (Cope Collection, No. 7380.)

Principal characters of Boöchœrus humerosus: On comparing *Boöchœrus humerosus* with *Dinohyus hollandi* it is quite apparent that the humerus in the former is relatively long and the manus[20] broad

[20] Although *B. humerosus* is heavier than *D. hollandi*, the feet of the former are considerably shorter and broader than in the latter.

(**21,** p. 168) and short (see figs. 15 and 16). The absence of an articular facet for mt. III[21] on the lower tibial angle of the cuboid in the John Day form is also a noticeable feature. *Boöchœrus humerosus* differs from *Archæotherium ingens* by the absence of the trapezium and by the fact that the unciform and magnum do not

FIG. 16. Left Humerus of *B. humerosus* Cope. About $\frac{1}{6}$ nat. size. (Cope Collection, No. 7380.)

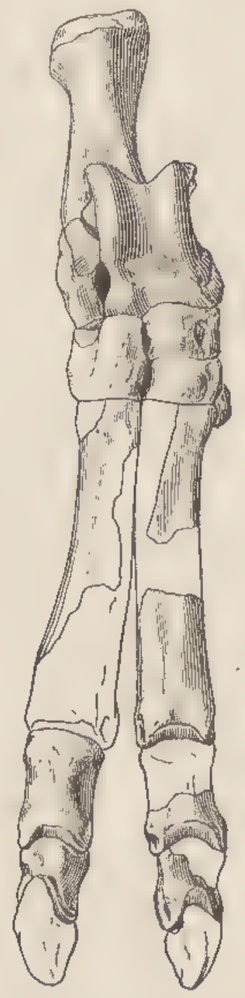


FIG. 17. Right Hind Foot of *B. humerosus* Cope. (Cope Collection, No. 7380.) $\frac{1}{6}$ nat. size.

touch one another dorsally when in position in the carpus.[22] From both *Dinohyus hollandi* and *Archæotherium ingens* the John Day subgenus differs by a relatively greater transverse diameter of the distal end of the femur.

Additional specimens from the John Day formation will undoubtedly give more complete information regarding this proposed genus. Cope states (**10,** p. 60) that the "remains indicate an animal of the size of the *Rhinoceros indicus.* The animal is characterized by the massive proportions of the humerus as compared with the femur, and by the short robust form of the metapodials."

[21] The head of mt. III in the type of *Boöchœrus* is restored on the fibular angle, but it was evidently the same as in *Archæotherium ingens,* judging from the absence of the facet on the lower tibial angle of the cuboid.

[22] Cope says (21, p. 171) that the lunar has penetrated so far as to almost divide the second row of carpals.

Genus DÆODON Cope.

A description of this genus was given by Professor Cope in a paper (**9,** p. 15) read before the American Philosophical Society, November 15, 1878, and published on December 3, of the same year. Owing to the very poor condition of the type, Cope

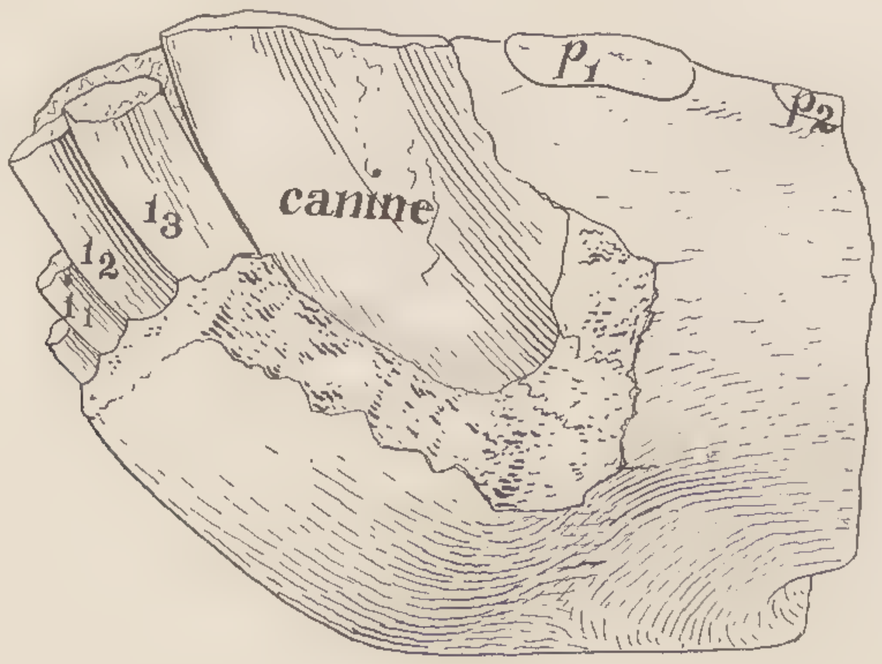


FIG. 18. Type of *Dæodon shoshonensis* Cope. About ½ nat. size. Cope Collection, No. 7387. Oblique View to show symphysis.

was unable to give any characters, except the absence of the osseous tuberosities on the anterior under borders of the lower jaws, which differ from those of the American Entelodonts generally. Cope placed *Dæodon* in the suborder Perissodactyla and associated it with *Titanotherium* and *Chalicotherium.* The genus has hitherto been regarded as belonging to the Perissodactyla and Zittel (**99,** p. 304) referred to it with a misprint under the name *Daledon* in connection with the synonymy of *Titanotherium.*

The fortunate discovery of additional material, which undoubtedly belongs to this genus, by the California University and published by Dr. W. J. Sinclair (**89,** pp. 132–134), furnishes much welcome light on the subject, and it now appears that *Dæodon* may confidently be removed from the Perissodactyla and placed in the family *Entelodontidæ.*

Principal Generic Characters of Dæodon: Chin without knob-like processes on the under border; posterior mandibular protuberance small and hollow; a gradual backward slope of the dependent angle of the lower jaw; jugal process with a moderate downward extension; fibula not[23] coössified with the tibia.

[23] In a letter from Dr. E. L. Furlong, of the California University, Berkeley, California, he assures me that "there is no fusion of the shaft of the fibula with the tibia."

Dæodon shoshonensis Cope.

Type: Symphysis of lower jaws.

Horizon: (Upper?) John Day Formation.

Locality: Bridge Creek, Wasco County, Oregon.

Locality of Type: The American Museum of Natural History (Cope Collection, No. 7387).

The principal characteristics of the type are the absence of the osseous bosses on the chin and the evenly rounded under surface of the symphysis. Only the roots of the teeth are preserved in the alveolar border of the type. These show that there were three incisors, a canine, and two premolars. The roots of the median pair of incisors are laterally compressed and indicate that they were small as in *Dinohyus hollandi*. $I_{\overline{2}}$ and $I_{\overline{3}}$ were evidently much increased in size, $P_{\overline{1}}$ is close to the canine and $P_{\overline{2}}$ is separated from $P_{\overline{1}}$ by a short diastema as in *Dinohyus*. That Professor Cope had compared the type of *Dæodon* with *Archæotherium* is evident from his statement (**9,** p. 15) that "the canine teeth are very robust, as in the species of *Elotherium*," but he associated *Dæodon* with *Chalicotherium* and *Titanotherium*, perhaps wholly on account of the absence of the large dependent processes of the chin. In this connection I may state that the symphysis of *Moropus* is much more procumbent and is of a decidedly more delicate structure than in the type of *Dæodon*. No Titanotheres have as yet been found in the John Day horizons, while Entelodonts of the same size are sometimes discovered.

MEASUREMENTS OF THE TYPE SPECIMEN OF *Dæodon shoshonensis*.

	Mm.
Greatest antero-posterior diameter of symphysis [24]	164
" transverse " " " at $P_{\overline{1}}$	144
Vertical diameter of ramus at $P_{\overline{2}}$	100

Dæodon calkinsi (Sinclair).

Type: Skull, several vertebræ, and portions of fore and hind limbs.

Horizon: Upper part of the *Promerycochœrus* beds.

Locality: Bridge Creek, Wheeler County, Oregon.

Locality of Type: Paleontological Collection of University of California, No. 953.

From the description and figures of *Dæodon* (*Elotherium*) *calkinsi* (**89,** p. 134, Pl. XV) it is quite evident that the specimen pertains to the genus *Dæodon* described by Cope in 1878 (**7,** p. 15). Although the type of the latter represents an animal of considerably larger size, it agrees perfectly, so far as comparison can be made, with the species described by Sinclair. The character by which *D. calkinsi*

[24] The alveolar border is broken, which naturally reduces the antero-posterior diameter to some extent.

is specifically to be separated from *D. shoshonensis* is principally the smaller size, so far as can be determined by comparison of the two. Sinclair states that the type of *D. calkinsi* represents a very old individual and that many of the teeth are shed and

FIG. 19. Outline of Illustration of Skull of *Dæodon calkinsi* (Sinclair). (After Sinclair.)

the alveoli closed. "P_2 . . . resembles the smaller premolars of the upper series. Anterior and posterior cingula are well developed on the lower molars. In M_3 the hypoconulid is not differentiated from the posterior cingulum, which projects slightly, forming a very small heel. . . .

"The mandible is peculiar in the absence of the knob-like bosses on the chin The protuberances beneath P_4 are small and deeply cupped. The dependent angle slopes gradually backward without the abrupt downward curvature characterizing *E. ingens*. . . .

"The chief point of specific value attaching to the cranium is in the shape and direction of the jugal processes. These processes are plate-like with a thickened median rib. The free edges, especially the anterior, are thin and sharp. The processes are short, not extending below the lower mandibular border. The orbits are posterior in position, their anterior borders lying above the posterior edge of M^3."

The unciform and tibia were kindly sent to the writer for purposes of study by Professor John C. Merriam of the University of California. It is at once noticeable that the lunar facet of the unciform is more elevated than in *Dinohyus* and

that the small facet for the magnum on the proximo-radial angle is more nearly radially in position as in the Oligocene genus *Archæotherium*. The unciform and magnum apparently articulated dorsally as in the latter genus. There are otherwise no marked differences between these two bones in *Dæodon* and *Dinohyus*.

MEASUREMENTS OF UNCIFORM.

	Mm.
Greatest antero-posterior diameter	43
" transverse "	40
" vertical "	35

The tibia in general resembles that of the Oligocene type rather more strongly than the later Miocene form. The fibula was not coössified with the tibia, although a rough border on the fibular side of the tibia indicates that the two bones were in close proximity to each other. On the anterior termination of the intertrochlear ridge of the distal end of the tibia is a facet, which indicates that upon extreme forward flexure of the tibia this facet articulated with a corresponding facet in the large pit on the anterior face of the astragalus, as in *Dinohyus*. The general features of the tibia are otherwise quite similar to those in the Entelodonts generally. The proximal end of the tibia is wanting, as is also the external portion of the distal end, in the specimen here described.

MEASUREMENTS OF TIBIA.

	Mm.
Greatest length of the fragment	276
" transverse diameter of shaft, medially	40
" antero-posterior diameter of shaft, medially	32
" " " " " distal end	42

Genus DINOHYUS Peterson.

(Plates LV–LXI.)

In 1905 the writer sent from the field the original description of this genus to Dr. W. J. Holland, Director of the Carnegie Museum, who suggested the name *Dinochœrus;* the description was published in Science (**78,** pp. 211–212). Later *Dinochœrus* was found to be preoccupied, and a note of correction by the writer appeared the same year in Science (**79,** p. 719). The skull and lower jaws were published in 1907 (**81,** pp. 49–51, Pls. XVI–XVII) and the detailed description of the skeleton is found on pages 77 *et seq.* of this memoir.

Dinohyus hollandi Peterson.

Type: A nearly complete skeleton.

Horizon: Lower Miocene (Lower Harrison beds).

Locality: Agate Spring Fossil Quarries (Quarry No. 1), Sioux County, Nebraska.

Locality of Type: The Carnegie Museum (Catalogue of Vertebrate Fossils, No. 1594).

Principal Generic Characters of Dinohyus: Median incisor reduced and sometimes wanting. Transverse diameter of $P^{\frac{3}{3}}$ nearly equal to the antero-posterior, $P_{\frac{4}{4}}$ with large deuterocone; the crown subquadrate in outline and the tooth of relatively small size; a tendency to increase the antero-posterior diameter of $M^{\frac{3}{3}}$, and the meta- and hypocones of relatively large size; lower molars with subequal height of posterior and anterior tubercles; the tubercles separated by narrow cross-valleys; the trigon lost; all the premolars spaced; dependent process of the jugal of proportionally small size and the posterior termination of the zygomatic process developed into a strong buttress at the anterior border of the glenoid cavity; small bony eminences on the chin and a strong knob-like process on the inferior border of the ramus opposite $P_{\frac{4}{4}}$; a relatively gradual backward slope of the angle; relatively short alveolar border of the premaxillary and rather short chin; vertical and transverse canals of the dorsal vertebræ as in *Sus*; fibula coössified with the tibia; trapezium absent and mt. V sometimes absent.

Genus AMMODON Marsh.

Although Professor Cope (**5,** p. 704), Leidy (**50,** p. 388), and Marsh (**57,** p. 3), referred to the New Jersey specimen, there was no adequate description of the type until 1893, when the latter author gave a short description together with good illustrations (**63,** pp. 409–410).

Known Generic Characters of Ammodon: $P^{\frac{4}{4}}$ of relatively large size; large hypoconulid on $M_{\frac{3}{3}}$; anterior and posterior tubercles of lower molars subequal in height; the loss of the trigon; cross-valleys narrow; type representing an animal of large size.

Ammodon leidyanum Marsh.

Type: $P_{\frac{4}{4}}$; Neotype: $M_{\frac{3}{3}}$ of left[25] side.

Horizon: Middle Miocene?

Locality: Near Farmingdale, Monmouth County, New Jersey.

Locality of Type: Collection of Yale Museum, No. 12040.

From Marsh's description (**63,** pp. 409–410) and also from my observations upon the specimen it seems quite probable that $P_{\frac{4}{4}}$ and $M_{\frac{3}{3}}$ which Marsh described belong to the same individual. Working on this hypothesis it would seem that $P_{\frac{4}{4}}$ is of greater proportionate diameter than in *Dinohyus hollandi*. The posterior heel of $P_{\frac{4}{4}}$ in *Ammodon* is also larger than in *Dinohyus*, which is due to a heavy

[25] Professor Marsh mistook the left $M_{\frac{3}{3}}$ for that of the right side, a mistake which might lead to confusion.

cingulum surrounding it in the former genus, but which is absent in *Dinohyus*. Furthermore, in the type of *Ammodon* the crown is somewhat higher and on the posterior face there are two mammilated ridges of considerable prominence

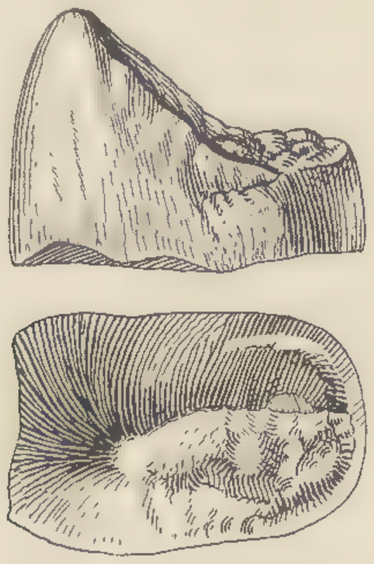


FIG. 20. Type of *Ammodon leidyanum* Marsh. Internal and Crown View of $P_{\overline{4}}$. $\frac{2}{3}$ nat. size. (Collection Yale Museum, No. 12040.)

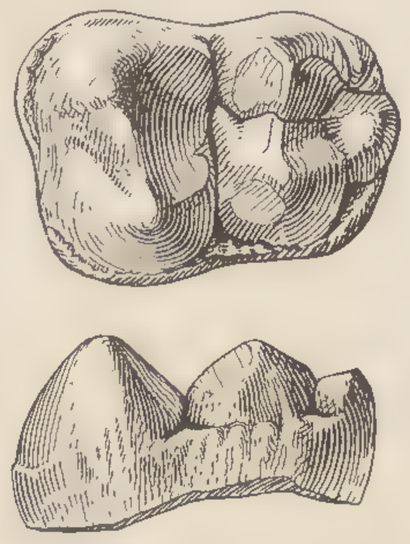


FIG. 21. External and Crown View of M_3 of Neotype of *Ammodon leidyanum*. $\frac{2}{3}$ nat. size. (Collection Yale Museum, No. 12040.)

which take their origin, one at the postero-internal angle and the other at the antero-external angle of the heel, and continue to very near the apex of the crown (see fig. 20). In *Dinohyus hollandi* there is only a slightly uneven folding of the otherwise smooth enamel on the posterior face of the protoconid, and there are no decided ridges. $M_{\overline{3}}$ of *Ammodon leidyanum* is very similar to that in *Dinohyus hollandi*. In the former the posterior heel (hypoconulid) is of relatively greater development (see fig. 21) than in the latter, and the tooth has a continuous cingulum on the antero-external and antero-internal faces, while the corresponding tooth in *Dinohyus* has the cingula represented on the postero-external, and but very slightly on the external and internal angles of the anterior face. The teeth of *Ammodon leidyanum* are larger than those in *Dinohyus* and represent an even more modified type than the latter.

FIG. 22. External and Dorsal View of Fragment of Astragalus of *Ammodon?* $\frac{1}{2}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 1548.)

Unfortunately the type of *Ammodon* is rather inadequate and consequently the basis of comparison is very limited, but the characters enumerated above would seem to indicate that the geological horizon in which the New Jersey specimen was found, represents

deposits as late, or perhaps later, than the lower Harrison beds of Nebraska, in which the type of *Dinohyus* was discovered.

In this connection it is of interest to note that a portion of an astragalus of an *Entelodont* of very large size was found in 1901 on the surface near the top of the upper Harrison beds in the upper Niobrara valley. This fragment (No. 1548, Carn. Mus. Cat. Vert. Foss.) although considerably worn by the elements, plainly indicates characters that are different from those in the corresponding bone of *Dinohyus*. Not only is the bone larger in size, but its sustentacular facet is proportionally of greater vertical convexity and the distal portion of the bone is produced anteriorly to a much greater extent than in *Dinohyus*. This peculiar feature of the astragalus under description would seem to indicate that the tarsus of this genus (*Ammodon?*) had a somewhat different angle.

Species the Generic Location of Which is Doubtful.

Elotherium imperator Leidy.

Type: A canine, an incisor, and a portion of the crown of a premolar tooth.
Horizon: Middle John Day beds?
Locality: Bridge Creek, and John Day River, Oregon.
Locality of Type: National Museum, Washington, D. C.?[26]

The first specimens of Entelodonts, which Professor Leidy reported from the John Day Basin in 1873 (**53,** pp. 217, 320), are altogether indeterminable generically and specifically and consequently inadequate as types. "*Elotherium imperator*" should therefore be regarded only as an historical record of the first report of the existence of Entelodonts in the John Day formation.

Elotherium superbum Leidy.

Type: An incisor tooth.
Horizon: Miocene?
Locality: Douglass Flat, Calaveras County, California.
Locality of Type: Unknown to the writer.

The type of "*Elotherium superbum*" is altogether inadequate, and its geological horizon is apparently uncertain. The record (**49,** p. 175; **50,** p. 388) of this species should be regarded as only possessing value from the standpoint of history and geographical distribution.

[26] No catalog number at this writing has been given to the specimens.

The History of the Discovery of the Agate Spring Fossil Quarries, Where the Skeleton of Dinohyus Hollandi was Found.

While engaged in field work for the Carnegie Museum on the upper Niobrara River, locally known as Running Water, Sioux County, Nebraska, in 1904, the writer had often been invited by Mr. James H. Cook to visit his ranch, the Agate Spring Stock Farm, located on that stream, some twenty-five or thirty miles east of the Nebraska-Wyoming state line. One day in the latter part of July, I decided to break camp and go down the river in search of new localities for fossils and also to study the geological features of the neighborhood more fully. As Mr. Cook's ranch was on our way down the stream, it was decided to pay him a visit, and accordingly we stopped at his ranch. After a camp-ground had been pointed out to me,

Fig. 23. Ranch-House of Mr. James H. Cook, Agate Spring Stock Farm. (From a photograph by Mr. Albert Thomson.)

on top of a high butte immediately to the south of the farm buildings, and arrangements for wood, water, etc., had been made, the preliminary work of prospecting the neighborhood was at once under way. A day or two later Mr. Harold Cook, the eldest son of Mr. James H. Cook, accompanied the writer to a small elevation some four miles to the east of the farm buildings and immediately beyond the east-

ern limits of the land belonging to the ranch.[27] The talus of this low hill was discovered to be filled with fragments of bones, and was afterwards designated as quarry A (See fig. 24, A). On our return to the ranch I reported to Mr. James H. Cook

FIG. 24. View of the Buttes Showing the Location of the Different Quarries. Nos. 1-3, Quarries of the Carnegie Museum. AM, American Museum of Natural History. NU, University of Nebraska. A, Quarry A. (From a photograph by the writer.)

that the place which his son had shown me was of much interest and importance to me and that I wished to start the work of excavation on the prospect immediately. This was entirely satisfactory to Mr. Cook and his family. In fact there was evident satisfaction on the part of Mr. Cook that I had found something which I regarded as of interest and importance near his farm, and I was accorded every civility, which I could possibly desire. As I wished to be near my work, Mr. Cook invited me to camp in his "lower field." Accordingly our first camp was pitched on the south bank of the stream close to the hill and the operation of excavating in quarry A was begun during the last few days of July. We had worked three or four days in this quarry when I decided to visit the two buttes (since named Carnegie Hill and University Hill by Prof. E. H. Barbour) which lie about three hundred yards to the south of the place where we were working. One may easily imagine the thrilling excitement of a fossil-hunter when he finds the talus of the hillsides positively covered with complete bones and fragments of fossil remains.

It was with comparatively little effort that I was able to articulate portions of

[27] Mr. James H. Cook informed me that fall that the hills containing the fossils were on his ground (80, p. 487); this statement was found afterward to be founded upon an error, and Mr. Harold Cook has since (1908) filed on this government land.

the feet of *Diceratherium cooki* and *Moropus* using the disassociated bones picked up in great abundance in the talus. Here then was a veritable wonderland! I spent a considerable portion of the afternoon before I returned to where my assistants, Mr. T. F. Olcott and A. A. Dodd, were at work. The next day I again returned to the hills with wrapping paper, twine, and a sack in order to pack and bring down the bones which I had picked up the previous day; and also to more fully ascertain, if possible, the extent of these deposits. A few days later when I reported my additional find to Mr. Cook, I learned that I was perhaps not the original discoverer of the bones in these two hills, as he told me that he had seen bones there as long

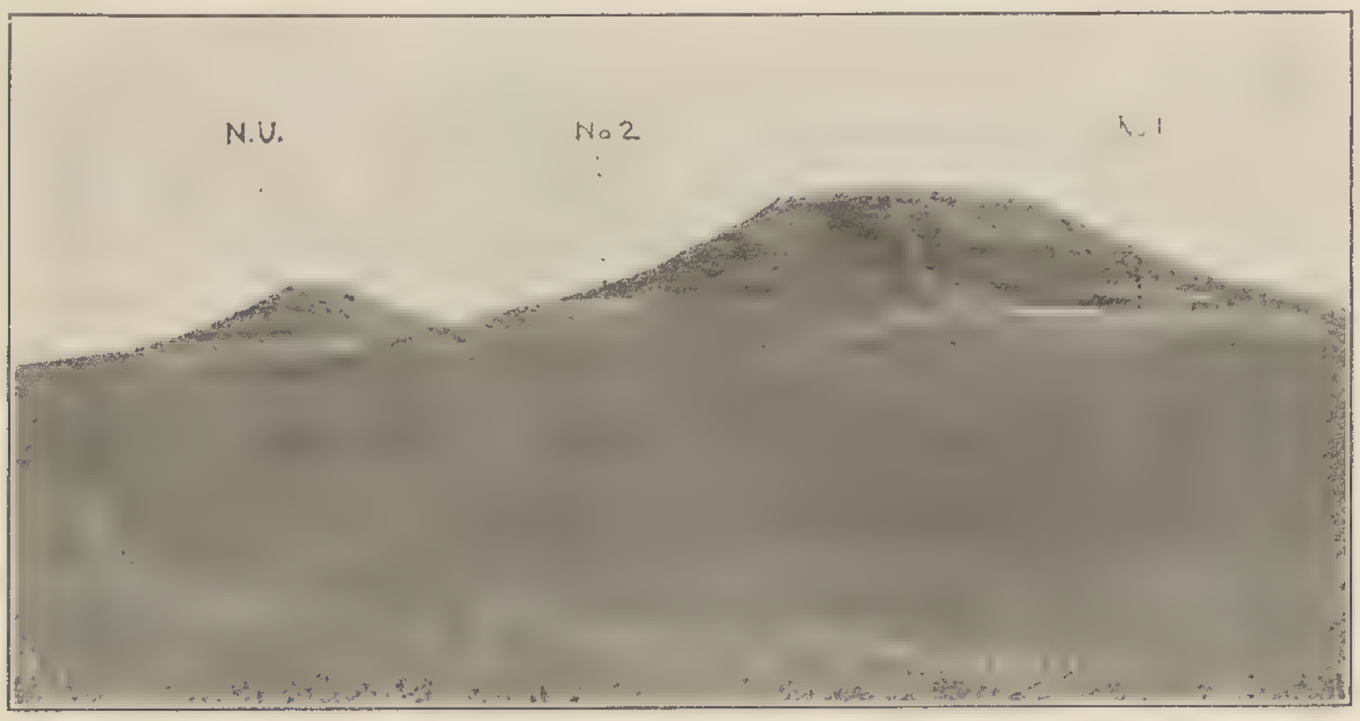


FIG. 25. View of Carnegie Hill and University Hill, Showing Quarries No. 1 and No. 2 of the Carnegie Museum on Carnegie Hill, and Quarry of the University of Nebraska to the left. (From a photograph by the writer.)

ago as 1890, but always thought them to be of recent origin. In 1908 I was further convinced that the bones in these hills had been seen even earlier by Mr. Octave Harris,[28] a prominent ranchman of the neighborhood. To Mr. Cook is, however, due much credit, as these deposits of bones would perhaps not have been brought to the attention of paleontologists at this time, had he not invited me to his ranch.

In looking over the whole situation it was plain that the deposits required more time and assistance than I then had. Together with this fact I may mention that I had not been well all that spring; in fact I was obliged to leave the field on account of sickness about the middle of August. I wish to here acknowledge, with much appreciation, the kind and sympathetic treatment I received from Mr. Cook and his family during my week of sickness at his ranch. Before leaving for the east

[28] Mr. Harris extended much aid to our party during our last (1908) season's work in the quarry, and the interest which he took in our work is heartily appreciated and most gratefully acknowledged.

I assured Mr. Cook that I would be back the following spring to systematically take up the work in the hills, which decision he assured me was in accord with his wishes.

Early in the spring of 1905 the writer accompanied by Mr. T. F. Olcott resumed work in quarry No. 1 (see fig. 25). Mr. Cook impelled by curiosity had already started in the previous fall to excavate in quarry No. 1 (see Plan of Quarry, Pl. LIV, Cook Excavation), but after earnest entreaty by letter to await the coming of more expert help desisted from his work. Many piles of fragments were found on the edge of the opening which had been dug out by Mr. Cook. These fragments were carefully gathered and packed before the commencement of systematic excavations. The work being fairly started, Mr. Olcott was left in charge of the quarry, while I returned to Pittsburgh in order to attend to other duties in the museum. Thus was started one of the most important fossil quarries ever found in North America.

When I again returned to the field later in the season, Mr. Olcott was still engaged in the same hill, while Professor E. H. Barbour, of the Nebraska State University, had been invited by Mr. Cook to open a quarry in the adjoining hill, afterwards named by Professor Barbour "The University Hill." Much material had been uncovered in quarry No. 1 among which the most important were bones of *Moropus*, many individuals of *Diceratherium* and an unusually well preserved, and pretty nearly articulated skeleton of a gigantic Entelodont (see Pl. LIV, Plan of Quarry, Blocks Nos. 61, 86 in Sect. 4). The discovery of the latter was a surprise, nothing having hitherto been found representing this family in the lower Miocene of Nebraska. One hind limb and most of the parts of the skeleton anterior to the pelvis were recovered. The pelvis, the lumbar vertebræ, and perhaps also one hind limb[29] were unfortunately dug out by Mr. Cook and those assisting him and only portions of four vertebræ and the pubic symphysis of the pelvis were recovered from the fragments left on the edge of the quarry.

The skull was almost in contact with the atlas. The cervical and dorsal vertebræ were found in a successive series back of the skull, the dorsals being articulated by their zygapophyses (see Plate LIV, Sect. 4, Blocks 61, 72, 86). The greater number of the ribs and the sternum were found in close proximity in their relative positions, while one hind limb was found a short distance from the main portion of the skeleton. The fore feet were scattered. There is, then, no doubt that the following description of the skeleton is that of one individual.

In addition to this skeleton there were found, in Sections 16–21 in quarry No.

[29] The head of a femur, which may or may not pertain to this specimen, was found on the dump.

1, opened in 1908 by the writer, many other bones, fragments, and scattered teeth of *Dinohyus*. Some of these fragments were much worn by the elements before they were finally deposited, indicating that they were probably transported by a

FIG. 26. At Work at the North End of Quarry No. 1. (From a photograph by Professor Barbour.)

stream of water. When this additional material is used in this paper its catalog number is always mentioned in connection with the description.

GEOLOGICAL NOTES.

The lower Miocene of western Nebraska and eastern Wyoming has been subdivided into four horizons. Successively overlying the Oligocene formation these horizons are: (1) the Gering beds; (2) the Monroe Creek beds; (3) the lower Harrison beds; (4) the upper Harrison beds. The latter horizon is capped at Spoon Butte and other high elevations on the divide between the Niobrara and Platte rivers, by a hard stratum of pinkish-gray sandstone (**81,** p. 23, fig. 1; **72f,** p. 73). This sandstone is from twenty-five to fifty feet (or about seven to fifteen meters) thick. No fossils have been found in this stratum on Spoon Butte by which its relative age can be determined. It is perhaps of considerably later origin than the Harrison beds, and may even be as late as the Pliocene. For convenience in this connection these beds may be called *The Spoon Butte beds.*[30]

It also appears, judging from the fauna of the upper Harrison beds, that this

[30] From a recent publication by Dr. Matthew (Science, N. S., Vol. XXIX, No. 735, p. 196, 1909) it would seem that these beds may be regarded as representing the Ogallala formation.

horizon of the Miocene exposed along the upper Niobrara, should be regarded as the base of the middle Miocene, or a horizon filling, in part at least, the hiatus between the lower and the middle Miocene. Places of non-conformity between the upper and lower Harrison beds are frequently found, the first of which observed by the writer in 1901 is situated immediately east of the Niobrara-Wyoming State line.

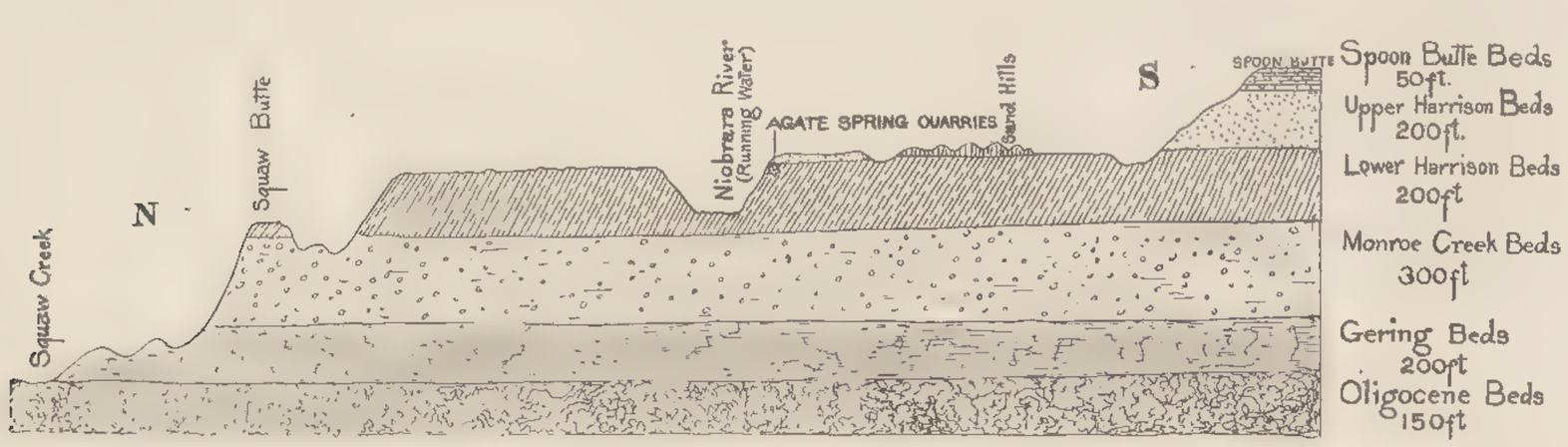


FIG. 27. Diagrammatic Section of the Miocene Beds in Western Nebraska and Eastern Wyoming.

This is in reality the type locality of the upper Harrison beds, which were called to J. B. Hatcher's attention by the writer in 1901. Hatcher, then Curator of Paleontology of the Carnegie Museum, decided these beds to be the "Nebraska beds" of Scott. Viewing these beds from the standpoint of certain portions of the fauna (**81,** p. 56) taken together with lithological characters, the sediment being usually of a darker color, it would seem that a natural division between the lower and middle Miocene may be established at the contact of these two horizons.

As has been stated elsewhere (**80,** p. 487; **81,** p. 41) the Agate Spring Fossil Quarries are located in the lower Harrison beds. The origin of the deposit in which the fossil bones of these quarries are found is most likely a stream deposit. In support of this view may be cited the fact that the parting plane underneath the layer carrying the bones is a few shades darker in color than that layer itself, and the

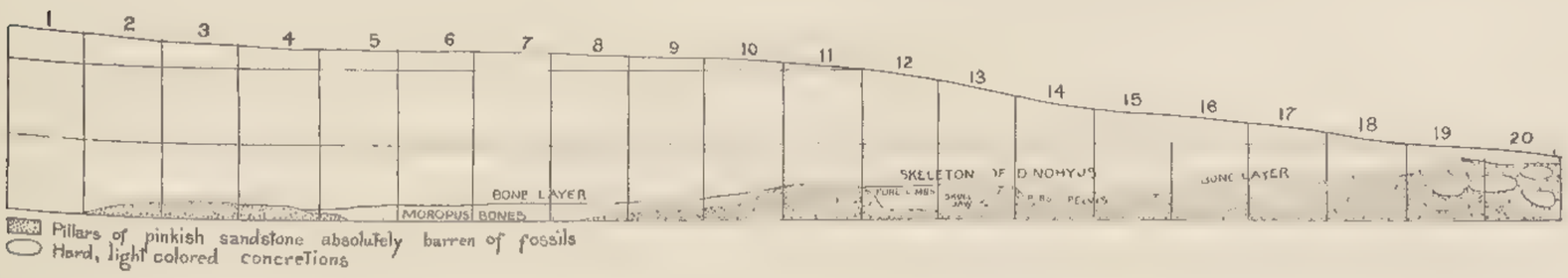

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
BONE LAYER
MOROPUS BONES
SKELETON OF D NOHYUS
BONE LAYER
Pillars of pinkish sandstone absolutely barren of fossils
Hard, light colored concretions

FIG. 28. Section of Face of Quarry of University of Nebraska at the End of the Season of 1908, showing channels in the stratum supporting the fossiliferous layers. The Nos. 1–20 indicate sections 5 ft. in length.

bones are often closely packed in irregular channels and pockets, which vary in thickness from two or three to eighteen or twenty inches (8 to 50 cm.). The surfaces of the bones are sometimes highly polished and worn, and there are numerous

fragments of bones which are worn down to the shape of a pebble. These conditions could have been brought about in no other way than by the action of water in motion. There was here most likely a stream of considerable magnitude, instead of a lake, as was suggested by the writer (**80,** p. 49). The fossil-bearing bed has all the appearance of a stream the bottom of which was covered by quick-sands. In the quarry located on "University Hill" (see fig. 28) there are distinct evidences of narrow and rather shallow channels, which were separated by sandbars of greater or lesser dimensions. The bone-layer of this quarry is thus, irregularly separated, although confined to one general level throughout portions of the base of the hill.

It seems reasonable to suppose that in the immediate vicinity of the Agate Spring Fossil Quarries the ancient fauna of the region found a favorite crossing of this stream. The remains of the unfortunate animals which attempted to ford the river under unfavorable circumstances furnish the records which the collector is fortunate in securing, and which give a glimpse into the struggle for existence in those early times.

In this connection it is interesting to note certain topographical features in the vicinity of the Agate Spring Fossil Quarries. In this region the general direction of the Niobrara River is east and west. Very often the side cañons of this stream extend in a direction contrary to that which one would naturally expect. The draws and cañons on the north side extend diagonally southeastward and in a perfectly natural direction towards the main stream, while very often the cañons on the south side extend diagonally northwestward or up-stream, which is generally regarded as a feature of stream piracy. This anomalous feature was quite perplexing to me for some time, and it was not until I had studied the character of the sediment in connection with the topography that any tangible explanation was reached. It is a well-known fact, which has been observed by Darton, Hatcher, Peterson, and others, that in these Miocene beds are masses of pipey concretions of greater or less extent, which always have their long axes directed in a nearly northwest-and-southeast direction. The cañons to the north of the Niobrara would have no difficulty in cutting their way through to the river in a natural course, while those on the south side of the stream would sometimes have to accommodate themselves to the up-stream direction which is the course of the least resistance to the erosive elements. In this way there are developed sharp ridges and hogbacks, nearly always in the northwest and southeasterly direction on either side of the river. Chimney-rocks and pillars of numerous shapes are seen along the course of the Niobrara River for some forty miles in this general locality.

The entire Miocene section, and especially the lower Harrison beds, are appa-

rently of considerably later age than the John Day formation in which Entelodonts have been discovered, judging from the fauna which has been published elsewhere (**81**, pp. 34–56). That some genera of the *Entelodontidæ* continued to the close of the lower Miocene is now well established; indeed it would perhaps not be surprising to find them represented in the middle and possibly in the upper Miocene. *Dinohyus*, which was discovered in the upper part of the lower Miocene beds (lower Harrison beds), was in all probability followed in the Miocene in New Jersey, by *Ammodon leidyanum*, which is without much doubt a later form.

Detailed Description of Dinohyus Hollandi Peterson.

The Superior Dentition.

(Plates LVII and LVIII.)

The median pair of incisors are lost in the type, but the alveolus of the right side is complete, and indicates a proportionally small tooth.[30a] $I^{\frac{2}{2}}$ is present and is much worn on the apex and the internal face; the tooth has a crowded position, and its antero-posterior diameter is greater than the transverse. $I^{\frac{3}{3}}$ is the largest of the incisors and is about twice the size of $I^{\frac{2}{2}}$; it has received much wear on the postero-lateral angle from contact with the inferior canine, and the apex is also much worn. The antero-posterior diameter of this tooth is, as in its predecessor, the greatest. All the incisors are more crowded than in the Oligocene forms generally. It is also noticeable that the transverse groove immediately above the enamel band, which Professor Scott refers to (**87**, p. 274), is very well developed in the type, and could not have been caused by the wear of the lower teeth.

Fig. 29. Oblique Side Views of Premaxillary Bone of *D. hollandi* Peterson. (Carn. Mus. Cat. Vert. Foss., No. 2145.)

As in other forms of the family, the canine tooth is very large, recurved, and has an enormous fang. In the present specimen the apex of the tooth has received considerable wear as has also the antero-internal face. There is a light cingulum on the posterior face, but externally the enamel is smooth.

The first, second, and third superior premolars in *Dinohyus* are in general quite similar in shape to the corresponding teeth in *Entelodon magnum* of Europe. They

[30a] A premaxillary bone (No. 2145, Carn. Mus. Cat. Vert. Foss.) in the collection from the Agate Spring Fossil Quarries, (Quar. No. 1, Sect. 19), which is here referred to *Dinohyus*, has only two alveoli, the median incisor having dropped out and the alveolus closed.

are, however, relatively small, $P\frac{4}{-}$ especially so, and the whole series is more spaced, while in the latter genus the second premolar forms a closed continuous series with the posterior teeth, and $P\frac{1}{-}$ only is widely separated by a diastema. In *Dinohyus* $P\frac{1}{-}$ and $P\frac{2}{-}$ are widely separated and $P\frac{2}{-}$ and $P\frac{3}{-}$ are separated only by a very short diastema. Back of $P\frac{3}{-}$ the dentition forms a continuous closed series.

$P\frac{1}{-}$ is of relatively large size with a simple crown, the apex of which is placed well forward the cingulum is quite heavy on the antero-internal angle and the

FIG. 30. Upper Right Canine of Type of *Dinohyus hollandi* Peterson. $\frac{3}{4}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 1594.)

heel slopes rapidly behind. $P\frac{2}{-}$ is of about the same size and shape as $P\frac{1}{-}$, except that the antero-internal cingulum is slightly more developed and extends further toward the external face of the tooth. The enamel of this tooth is less crinkled than that of $P\frac{1}{-}$. $P\frac{3}{-}$ has a relatively smaller antero-posterior and a greater transverse diameter than in the Oligocene forms. This transverse enlargement of the tooth

causes a characteristic trihedral cross-section, which is very much less apparent in the forms from the Oligocene. The tooth is slightly larger than $P\frac{4}{}$. The entire crown is practically taken up by the large protocone. The cingulum has developed into a narrow shelf on the antero-internal angle and continues in a much less conspicuous manner on the internal face, terminating in the heavy cingulum posteriorly. $P\frac{4}{}$ has no cingulum externally, which is also true of all the other premolars, and its transverse is slightly greater than its antero-posterior diameter. The tooth has a proto- and a deuterocone. The latter is relatively more developed than in *Entelodon*. There is a heavy cingulum posteriorly and on the antero-external angle a prominent basal heel is developed, but there are no external or internal cingula.

The molars of *Dinohyus* are more specialized than those of *Archæotherium*, as is shown by the fact that the tubercles of the crowns are more depressed and consolidated, and the posterior portion of $M\frac{3}{}$ is relatively more developed than in the Oligocene genus. The crown of $M\frac{1}{}$ in the type specimen is much worn, so that it shows two large and irregular tracts with the bottom of the cross-valley extending beyond the triturating surface, especially on the inner portion of the tooth. There are heavy cingula anteriorly and posteriorly and a less developed cingulum externally, while internally the tooth is smooth. $M\frac{2}{}$ is the largest of the series; the principal difference between it and the corresponding tooth in the Oligocene forms (especially those from the lower Oligocene) is revealed in the interruption of the internal exit of the cross-valley by a heavy rounded ridge (see Pl. LVIII, fig. 1) which was undoubtedly developed from the cingulum. The anterior border is entirely surrounded by a heavy cingulum, as is also the postero-external angle, while on the external face immediately back of the exit of the cross-valley there is very slight indication of a cingulum. The posterior portion of $M\frac{3}{}$ is composed of (1) metacone, (2) hypocone, and (3) metaconule; the first is of much larger size than the second, and the third is very inconspicuous, in fact it is entirely absent on the corresponding molar of the right side of the type specimen. The cross-valley of $M\frac{3}{}$ is interrupted in the same manner as is the case in the preceding tooth, and in addition this tooth has a mammillary cingulum which to some extent also closes up the external exit of the cross-valley. This cross-valley is not closed up in the specimens of *Archæotherium* known to me from the lower Oligocene. There is in the present type a heavy anterior cingulum on $M\frac{3}{}$, but no posterior cingulum; the back part of the tooth having played a more important part in the make-up of the crown in this genus than is seen in older types.

The antero-external tubercle of the last upper molar in *Entelodon magnum* has reached a greater development than in *Archæotherium* and in this respect is more

nearly like what is seen in *Dinohyus*. The posterior portion of this tooth in the latter genus is not unlike that of the European form, and shows a more advanced development than in *Archæotherium*. Altogether in *Archæotherium* the crowns of the molars are somewhat lower, the apices of the different points of the grinding surface are less united, and the teeth as a whole are less modified than in *Entelodon magnum* and *Dinohyus hollandi*.

MEASUREMENTS.

	Mm.
Length of alveolar border of maxillary and premaxillary	465
Distance from median incisor to M^1	330
Length of molar series	132
Antero-posterior diameter of I^2	28
Transverse " " I^2	24
" " " I^3	41
Antero-posterior " " I^3	35
" " " canine at base	50
Transverse " " " " "	53
Antero-posterior " " P^1	39
Transverse " " P^1	22
Antero-posterior " " P^2	38
Transverse " " P^2	22
Antero-posterior " " P^3	42
Transverse " " P^3	33
Antero-posterior " " P^4	37
Transverse " " P^4	40
Antero-posterior " " M^1	42
Transverse " " M^1	44
Antero-posterior " " M^2	45
Transverse " " M^2	48
Antero-posterior " " M^3	45
Transverse " " M^3	47

THE INFERIOR DENTITION.

(Plate LVIII.)

The incisors are much worn, but their outlines present more obtusely pointed crowns than in the older forms and the median pair is proportionately smaller, so that the gradual enlargement from $I_{\overline{1}}$ to $I_{\overline{3}}$ is in about the same proportion as in the superior series. The teeth are crowded and occupy a more nearly transverse position in the front of the jaws than is seen in the Oligocene forms generally. The crown of $I_{\overline{1}}$ is much worn; and its antero-posterior exceeds its transverse diameter, so that it is oval in cross-section. $I_{\overline{2}}$ is about twice the size of the median incisor and is also oval in cross-section, its antero-posterior being greater than its transverse

diameter. There is a heavy cingulum on the posterior face which extends half way around the base of the lingual side. $I_{\overline{3}}$ is nearly twice as large as the tooth just described, but otherwise the two are quite similar. On the external faces of $I_{\overline{2}}$ and $I_{\overline{3}}$ are deep grooves across the faces, just below the enamel band, which were not caused by the wear of the upper teeth. Inasmuch as the canines of both sides have a similar and much greater worn area externally, which could not have been reached by any of the upper teeth, it further supports the contention of Professor W. B. Scott and C. F. Brackett, that these animals used the lower tusks in digging in the ground for roots (**87,** footnote, p. 275). They may also have been used for stripping off the foliage of shrubbery. There is a slightly developed cingulum on the posterior face of the canine, otherwise the enamel is quite smooth. The crown is higher and more pointed than that of the upper canine, but in general appearance and size it differs little from that tooth.[31]

$P_{\overline{1}}$ is separated from the canine by a short diastema; the tooth is implanted in the jaw by two strong fangs which coalesce for some distance below the crown. The latter is simple and is rather low when compared with that of *Archæotherium.* On the internal face the enamel is crinkled, but externally the tooth is quite smooth. Posteriorly there is a heavy cingulum and anteriorly there is a prominent oblique ridge, which originates at the antero-internal angle and continues outward and upward to the apex, constantly diminishing in prominence in its upward course. The apex of the crown in the type is considerably worn, but it is quite easy to ascertain its contour which was very much more obtuse than in *Archæotherium.* There is a considerable diastema between $P_{\overline{1}}$ and $P_{\overline{2}}$. The latter is also implanted with two roots which are, however, more divergent and do not coalesce below the crown as in $P_{\overline{1}}$. The crown of $P_{\overline{2}}$ is of about the same size as the crown of the preceding tooth, but its apex is less worn and there is a mammillated ridge on the anterior and posterior faces of the protoconid. There are prominent anterior and posterior cingula and the enamel on the internal face is thrown into light folds, while the buccal face of the tooth is smooth. $P_{\overline{3}}$ is, as usual, the largest in the series; it is not crowded in the alveolar border, but is separated from $P_{\overline{2}}$ by a very short diastema. The apex of the crown is next highest to that of the canine and in general form it is not unlike that of $P_{\overline{2}}$. $P_{\overline{4}}$ has a heavy heel which agrees in general with $P_{\overline{4}}$ in *Entelodon magnum.* Altogether $P_{\overline{4}}$ of the present genus presents a different outline from that of the corresponding tooth in the earlier genera, which fact is wholly due to the increased transverse diameter of the tooth posteriorly.

[31] The left lower canine is disproportionately short and stubby and was evidently broken off at the apex during the life of the animal.

The inferior premolars of *Entelodon* are relatively large, more regular in size, and $P_{\bar{3}}$ and $P_{\bar{4}}$ are entirely surrounded by cingula; while in *Dinohyus* the premolar teeth as a whole are smaller, $P_{\bar{3}}$ being conspicuously the larger of the series and $P_{\bar{3}}$ and $P_{\bar{4}}$ have the cingula less strongly developed.

The molar series in *Dinohyus* is very crowded and occupies less than one half of the antero-posterior diameter of the alveolar border. As in other allied genera, the molars are of relatively small size in comparison with the jaw and they increase

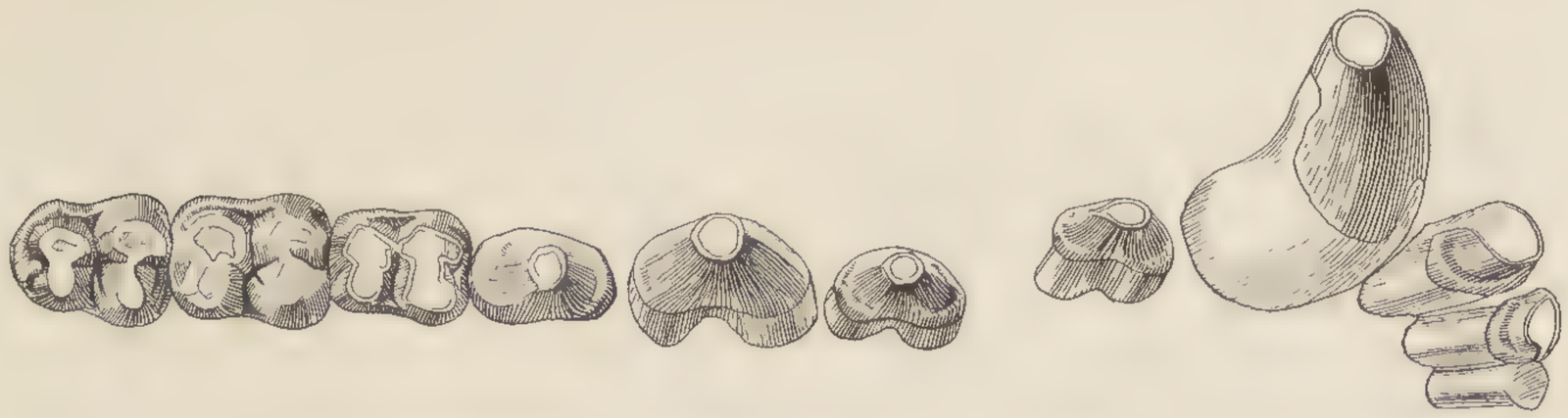


FIG. 31. Crown View of Inferior Dentition, Left Side. Type specimen of *Dinohyus hollandi* Peterson. $\frac{2}{5}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 1594.)

in size posteriorly. $M_{\bar{1}}$ is considerably worn in the type, so that the quadritubercular pattern is converted into two heavy transverse tracts having irregular outlines and with only a remnant of the cross-valley on the inner half of the tooth. On the antero-internal angle the cingulum is developed into a small basal tubercle. Opposite the cross-valley there are short and smoothly rounded cingula externally and internally. On the postero-external angle is a cingulum, which is continuous with a similar short cingulum on $M_{\bar{2}}$. The posterior face of the tooth is closely crowded against the anterior face of $M_{\bar{2}}$.

In the type the quadritubercular pattern of $M_{\bar{2}}$ is plainer than is the case in the tooth just described, but trituration has already caused the appearance of the solid cross-crests; the anterior being slightly more elevated than the posterior. Anteriorly there is a deep, narrow fissure, which is caused by projecting horns from the proto- and metaconids. On the external face the cingulum extends from the postero-external base of the protoconid and continues around the hypoconid, terminating in the posterior basal heel.[32] There is no cingulum on the external face of the protoconid, nor on the internal face of the inferior molars.

The proto- and metaconids of $M_{\bar{3}}$ are very little worn, so that the separation is still present, but it is reduced to a very narrow and shallow fissure on account of the

[32] In my preliminary notes on (*Dinochœrus*) *Dinohyus hollandi*, Science, Vol. XXII, p. 212, 1905, I made the statement that "There is no cingulum on the inferior molars," which is incorrect.

transverse development of the tubercles. The fissure which corresponds to that described on the anterior face of $M_{\bar{2}}$ is present on $M_{\bar{3}}$ but is entirely closed in by the lateral horns of the proto- and metaconids. There are slight cingula on the antero-external angles and the external face of the hypoconid is surrounded by a heavy mammillated cingulum. Posteriorly there is a heavy basal ledge and a minute hypoconulid which is located at the base (posteriorly), between the hypo- and entoconids. One of the more significant characters of the lower dentition is seen in the relatively greater development of the hypo- and entoconids, which causes the narrowing of the cross-valley between the latter and the anterior tubercles.

There were found in quarry No. 1, the third lower molars of the right and the left rami (Vert. Foss., 1835; 2114), which differ from $M_{\bar{3}}$ in the type of *Dinohyus*, by having the hypoconulid well developed. The cross-valley between the anterior and posterior tubercles is also interrupted externally by a heavy cingulum. The postero-external face of these teeth are otherwise quite smooth, while in *Dinohyus hollandi*, there is a continuous cingulum from the cross-valley to the posterior face of the hypoconid. These teeth may possibly represent another genus, but are inadequate as types.

The molars of *Entelodon* differ from those of *Dinohyus* in having the postero-internal cusp (entoconid), especially on $M_{\bar{2}}$ and $M_{\bar{3}}$ much less developed. The ledge produced by the cingulum on the posterior margin of the crown, which is so prominent in *Dinohyus*, is only very slightly represented in *Entelodon*. The cingula are also better represented on the molars of *Entelodon* than in those of the American genus. The most important feature of the lower dentition is seen in the greater development of the posterior portion of the crown of $M_{\bar{3}}$ in *Dinohyus* than in *Entelodon* which in the former is distinctly more specialized than in the latter genus. This same feature of $M_{\bar{3}}$ is also observed on comparing *Dinohyus* with *Archæotherium*.

MEASUREMENTS.

	Mm.
Length of inferior dentition	465
" from median incisor to $M_{\bar{1}}$	325
" of molar series	137
Antero-posterior diameter of $I_{\bar{1}}$	16
Transverse " " $I_{\bar{1}}$	12
Antero-posterior " " $I_{\bar{2}}$	25
Transverse " " $I_{\bar{2}}$	19
Antero-posterior " " $I_{\bar{3}}$ at the base of crown	34
Transverse " " $I_{\bar{3}}$ " " "	27
Antero-posterior " of canine " " "	48
Transverse " " " " "	45

Antero-posterior diameter of $P_{\overline{1}}$ at the base of crown						38
Transverse	"	" $P_{\overline{1}}$	"	"	"	21
Antero-posterior	"	" $P_{\overline{2}}$	"	"	"	40
Transverse	"	" $P_{\overline{2}}$	"	"	"	21
Antero-posterior	"	" $P_{\overline{3}}$	"	"	"	54
Transverse	"	" $P_{\overline{3}}$	"	"	"	28
Antero-posterior	"	" $P_{\overline{4}}$	"	"	"	45
Transverse	"	" $P_{\overline{4}}$	"	"	"	28
Antero-posterior	"	" $M_{\overline{1}}$	"	"	"	42
Transverse	"	" $M_{\overline{1}}$	"	"	"	34
Antero-posterior	"	" $M_{\overline{2}}$	"	"	"	47
Transverse	"	" $M_{\overline{2}}$	"	"	"	40
Antero-posterior	"	" $M_{\overline{3}}$	"	"	"	50
Transverse	"	" $M_{\overline{3}}$	"	"	"	39

The Milk Dentition.

(Plate LIX.)

In section 12, block 66 (see Plan of Quarry, Pl. LIV), were found the remains (No. 2137, Carn. Mus. Cat. Vert. Foss.) of the skull, and close by in another block, a portion of the lower jaw of a young individual, with the dentition partly in place. An incisor is represented only by the crown; the tooth being too young for the formation of a fang. This incisor is pressed by the matrix close to the canine and has a simple conical crown slightly crinkled at the base and it is very thinly covered by enamel. The only noticeable difference between this tooth and more adult forms of the canine is its strongly serrated anterior and posterior ridges and the crinkled enamel. By excavating the alveolar border at the antero-internal angle of the deciduous canine the crown of the permanent canine was found.

The point of the crown of the permanent $P^{\underline{1}}$ appears in the circular alveolus immediately back of the canine. It is thus seen that the temporary $P^{\underline{1}}$ had a single fang and was crowded out quite early. Professor Scott has also (**87,** p. 276) pointed out a similar occurrence observed by him in a young specimen of *Archæotherium* which would tend to firmly establish the fact that there are four deciduous premolars in the upper jaw of at least two genera of this family. Deciduous $P^{\underline{2}}$ of the specimen under description is represented only by the alveolus, while the deciduous $P^{\underline{3}}$ is in position in the right maxillary and $P^{\underline{4}}$ again represented by alveoli. In the left jaw temporary $P^{\underline{4}}$ has been placed in position. Deciduous $P^{\underline{3}}$ of this specimen has two large cusps and two smaller tubercles. The anterior cusp (protocone) is a bluntly pointed pyramid which occupies the anterior half of the crown, while the postero-internal cusp (tetartocone) is smaller, and is confined to about one quarter

of the tooth at its postero-internal portion. The two small cusps are nearly on a direct transverse line and immediately external to the tetartocone. Anteriorly and posteriorly there are very heavy cingula; externally and internally the cingulum is only moderately developed. The deciduous $P^{\frac{4}{}}$ was found quite close to its position and there is comparatively little, or no doubt, that this tooth belongs with this specimen. The tooth is molariform, as in the Oligocene genus (**87,** p. 287). It is strikingly similar to $M^{\frac{3}{}}$ of the permanent series, but has the antero-external portion of the cingulum developed into a more decided cusp.[33] Anteriorly there are three cusps on the crown: one internal, one external, and one directly anterior. The two former are of equal size, while the latter is quite small and occupies the anterior exit of the longitudinal valley. Posteriorly there are two subequal cusps which are separated from the anterior cusps by a deep cross-valley. The tooth is nearly surrounded by a cingulum.

FIG. 32. Supposed Deciduous Upper First Premolar. Nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2127.)

The chief feature of the maxillary bone is its comparatively short antero-posterior diameter. The premolar series is set closer together in the alveolar border than is the case in the adult; the preorbital foramen, however, seems to occupy the same relative position as in the latter. The palatine plate is quite thick, but its transverse diameter is small.

The milk dentition of the lower jaw is represented only by the last molar (No. 2137A, Carn. Mus. Cat. Vert. Foss.). The crown of this tooth is composed as usual of three transverse pairs of cusps and a small talon developed by the cingulum on the posterior face. The tooth is very long and narrow with broad transverse valleys separating each pair of tubercles, while the longitudinal valley is much less distinct. The crown is supported by two strong fangs which are bifurcated near their lower extremities. The posterior portion of a lower jaw (No. 2137A, Carn. Mus. Cat. Vert. Foss.) was found near the tooth described above and undoubtedly belongs to it. In this mandibular fragment the posterior alveolus for $dP_{\bar{1}}$ is still preserved, and into this the tooth referred to fits quite perfectly and is regarded by the writer as belonging to the same individual (see Pl. LIX, fig. 3). When the jaw is excavated from the inner side back of the last milk-molar there is seen the complete crown of $M_{\bar{1}}$, and only the anterior portion of $M_{\bar{2}}$. The crown of $M_{\bar{1}}$ is directed upward in the usual way, while that of $M_{\bar{2}}$ is directly inward, and would have to rotate outward and upward in order to erupt through the alveolar border in the usual manner. As is seen from the illustration (Pl. LIX, fig. 3) the two anterior

[33] Professor Scott evidently mistook the anterior part of the tooth he described for the posterior portion (*l. c.*, p. 276)

cusps of $M_{\overline{2}}$ are well united and apparently not developed independently, as in young titanotheres.[34] The posterior portion of $M_{\overline{1}}$ is not represented at all, as the tooth is too young.

The jaw fragment was somewhat worn by the elements before it was finally imbedded in the bone-bearing layer of the quarry. The coronoid process is, however, complete, and is low and broad antero-posteriorly. The condyle is on a horizontal line with the alveolar border and the angle is seen to project quite strongly downward below the ventral border of the jaw. The dental foramen is very large and is situated immediately in front of, and below, the condyle. The temporal fossa is high and very shallow.

An isolated upper tooth, which was found in the Agate Spring Fossil Quarries (Quarry No. 1) by Mr. Harold J. Cook and presented to the writer for publication, appears to be a deciduous upper premolar ($dP^{\overline{3}}$) of the right side (fig. 33). This tooth is surprisingly similar to an upper tooth of a carnivore (canid) and was so regarded by the writer for some time. Dr. W. D. Matthew kindly made a systematic comparison with the material in the large collection of the American Museum and suggested that it was perhaps a deciduous tooth of an Entelodont. The additional material secured in the Agate Spring Quarries during the season of 1908 enables us to correctly determine this tooth and it is here illustrated in order to assist the student. The chief peculiarity of this tooth is that instead of having three cusps on the posterior portion of the crown, as the tooth described above, it has only two, and in this respect agrees better with the tooth of *Archæotherium* described by Scott (**87,** p. 276). The portion of the posterior root which remains unbroken is abruptly pointed and short, having characters one would expect to find in a milk-tooth.

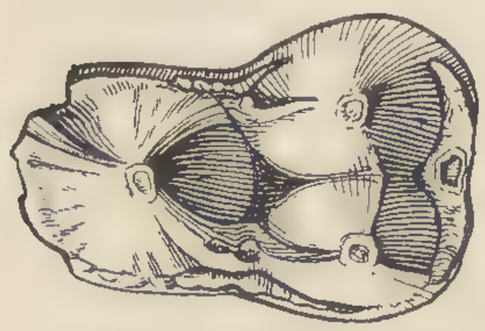


FIG. 33. Crown View of Deciduous $P^{\overline{3}}$ Left Side, *Dinohyus hollandi*. Nat. size. (Harold Cook's Collection.)

MEASUREMENTS.

	Mm.
Great diameter of the crown	43
Diameter across the paired tubercles	27

THE SKULL.

(Plates LV–LVIII.)

The orbits in the cranium of *Dinohyus* are so placed that the eye looked directly forward in an unusual manner (see Plates LVI, LX, and LXI). The eye is located

[34] Hatcher, Annals Carnegie Museum, Vol. 1, pp. 260–261, 1901.

well back in the skull, the face is very long, and the brain-case short. There is a well developed sagittal crest, and an overhanging occiput.[35] The descending broad and thin plate below the orbit is quite small when compared with some Oligocene species, and the zygomatic process of the jugal terminates in a heavy buttress, which forms the anterior border of the glenoid cavity. The comparatively gentle downward sweep of the angle of the lower jaw and the relatively small process on the ventral border of the chin are other features of importance.

The base of the skull has received considerable injury by crushing, and the sutures are entirely closed, but the character of the different bones are generally similar to, and agree quite closely with, the descriptions of those of the American Entelodonts given by Professors Leidy (**44,** pp. 57–67), Scott (**87,** pp. 278–287), and others. The basioccipital is short, slightly keeled ventrally, and has a rough area at its junction with the basisphenoid. The condylar foramen is of considerable size, and, as in *A. mortoni,* is placed some distance in front of the condyle. The exoccipital has a great transverse diameter at the base of the occiput and narrows rapidly superiorly. The condyles are well separated by broad notches superiorly and inferiorly, and their transverse diameters are a little less than three-fifths greater than the vertical, which agrees better with the American species than with *Entelodon magnum* of Europe. The foramen magnum is transversely oblong in a greater degree than is the case in the Princeton specimen, but this may in part be due to crushing. The paroccipital process is quite heavy, trihedral in cross-section, and terminates in a truncated and rugose free end; its position is similar to that in *Archæotherium mortoni* figured by Professor Scott (**87,** Pl. XVIII, fig. 2), but apparently relatively shorter.

The stylomastoid foramen and the pit for the tympano-hyal occupy apparently the same relative positions as in the Oligocene genus (see Pl. LVII), *i. e.,* anterior and external to the condylar foramen. The superior wing-like processes of the supra-occipital are crushed laterally, but I judge that in their normal condition they assume characters similar to the American forms generally. The basisphenoid, as in *Archæotherium ingens,* is narrow and not keeled ventrally. There is a canal in the median line, just at the point where the basisphenoid is concealed by the union of the palatines and pterygoids; this is also present in *A. mortoni* and has been figured by Scott (*l. c.,* Pl. XVIII, fig. 1). Whether or not there was a tympanic bulla in *Dinohyus* cannot be determined from the material at hand.[36] The pterygoids are much compressed laterally, but they extend well down and terminate in short and backwardly directed hamular processes. The foramen ovale is of considerable size and occupies

[35] This overhanging of the occiput in the type is due, to some extent, to crushing.

[36] In a well preserved skull of *Dinohyus hollandi* collected in the Agate Spring Quarries (University Hill Quarry) by Professor Barbour in 1908, there are no tympanic bullæ.

practically the same position as in the Oligocene genus, *i. e.*, just lateral to the ridge of the alisphenoid which leads to the pterygoids. The skull is distorted in this region, so that the peculiar conditions of the pterygoids, which Professor Scott describes (**87,** p. 283), cannot be ascertained from this specimen. The parietals extend well down on the side of the cranium and terminate superiorly in the high and sharp sagittal crest, which is rounded from before backward in a manner similar to what is observed in some other American forms. The sutural contact between the frontal, supraoccipital, and the squamosal is entirely obliterated. The frontals are very broad and much inflated over the orbits, terminating laterally in a heavy process, which meets its fellow of the jugal; the two are well coössified and form a heavy vertical bar, which completely encloses the orbit posteriorly. The orbit is of large size and faces forward and slightly outward. Immediately in front of the sagittal crest is a broad canal, which extends obliquely upward and backward, apparently piercing the cranial wall (see Pl. LVI). The exit of this canal leads into a depression on the frontals, which is of considerable depth and triangular in outline. This depression extends outward laterally by means of two large grooves, one on either side, running parallel with the temporal ridges, and by means of a broad anterior groove, which is continuous with the depressed median area of the frontals. On account of the enormous inflation of the frontals over the orbit and the great lateral extent of the postorbital process the eye was placed lower down and had a more direct forward look than in the older types of this family (see Pls. LV, LVI).

The zygomatic process of the squamosal has an enormous development, which seems to be relatively quite as great, if not greater, than is the case in the earlier forms. The lambdoidal crest descends steeply to a point immediately above the base of the paroccipital process; the border of the arch then rises again to form a broad, thin process similar to that in *Sus*, the peccary, and other ungulates. Anteriorly the zygomatic process forms the sutural contact with the jugal at the base of the orbital process. The temporal fossa thus has a tremendous transverse diameter, which is one of the chief characteristics of the cranium in this family. The glenoid cavity is well defined and its anterior border is provided with a strong buttress (the zygomatic process of the jugal referred to above), which seems to be a mark of evengreater specialization in this genus, than in the John Day forms, and has already been referred to in previous papers (**81,** pp. 49–51).

The jugal, as has been stated by Marsh, Scott, and others, constitutes one of the most extraordinary features of the skull in this family. Anteriorly the jugal extends but little on the side of the face, uniting by suture with the maxillary and the lachrymal. In its backward extension the upper margin forms the lower half

of the border of the orbit, and the lower margin descends rapidly to form the dependent, broad, and laterally compressed process, which is in *Dinohyus* considerably smaller than is the case in many earlier species. This anomalous process is directed slightly outward as well as downward, and no doubt varies in shape in different species, if not in different individuals; at all events this appears to be true of the Oligocene forms.[37] Superiorly the jugal sends out a postorbital process, which is coössified with that of the frontal, as stated above and the posterior process is received by the zygomatic process of the squamosal (see Pl. LV).

The lachrymal covers a considerable portion of the side of the face and articulates anteriorly with the maxillary, superiorly with the frontal, not with the nasal, and inferiorly with the jugal. The bone supplies a portion of the anterior border of the orbit. The lachrymal tubercle is quiet prominent.

The long and slender nasals articulate superiorly with the spear-shaped processes of the frontals, and laterally with the maxillaries and the premaxillaries. At their junction with the frontals the median area of the nasals is very convex transversely and on the sides of the muzzle the nasals have a slight inward bend to accommodate them to the concave sweep of the muzzle in front of the orbits. More anteriorly the nasals are regularly convex from side to side and gradually decrease in width; their anterior ends are slightly damaged in the type, but it is seen that their free ends are slightly separated in the median line, and also that they projected slightly beyond the superior border of the premaxillaries.

The premaxillaries are more truncated anteriorly than in the known Oligocene forms. This causes the reduction of the median pair of incisors stated above, and the anterior border ascends slightly more rapidly than in the earlier forms. Superiorly the premaxillaries have a long contact with the nasals and posteriorly they are received by the oblique border of the maxillaries. The premaxillaries are of large size, but are relatively smaller than those in *Hippopotamus* and *Sus*. The incisive foramina are large and the palatine processes of the premaxillaries are only thin bony bridges, which are suturally connected in the median line, and extend back opposite the posterior portion of the canine.

The maxillaries have a great antero-posterior diameter and the sides of the long and comparatively narrow muzzle are largely made up of these bones, although the lachrymal and the jugal cover a considerable space. The alveolar border forms an almost straight antero-posterior line until the canine is reached; at this point the maxillary has a rapid outward curve to accommodate the root for the large canine. The maxillo-premaxillary suture is somewhat short in comparison with that in older

[37] These processes are present in all of the American species, of which complete material, representing this portion of the skull, has been found.

forms. The infraorbital foramen is above the posterior part of P^3. The palatine plates are comparatively narrow transversely and have a considerable concavity in the same direction.

In the region of the palatines the skull is much crushed and the sutures are entirely obliterated, so that the outlines cannot be traced. The posterior nares are long and narrow, and extend anteriorly to opposite the anterior portion of $M\frac{3}{}$.

From Kowalevsky's illustrations (**38,** Plates XVI; XVII, fig. 5) it is evident that the base of the skull and the occiput in *Entelodon* is quite different from what is observed in the American forms. Judging from Kowalevsky's figures, the occipital condyle in the European form has a much greater vertical diameter in proportion to its transverse, the region of the paroccipital process extends further below the condyle, and the process itself is different in shape, being more compressed antero-posteriorly, expanded transversely, projecting well downward, and terminating in a rounded point. The base of the zygomatic process of the squamosal is in contact with the paroccipital process not unlike what is seen in *Sus* (See fig. 2 on page 45). The anterior face of the paroccipital process (see Kowalevsky, Pl. XVI), where we should expect to find the solidly fused region between the base of the paroccipital process and the postglenoid similar to that in the American Entelodonts, shows a remarkable similarity to what is seen in *Sus*, and it would not be surprising to find the external auditory meatus situated higher up on the cranium in *Entelodon* than is the case in the American species. In examining the posterior view of the skull of *Entelodon* (*l. c.*, Pl. XVII, fig. 5) it is at once observed that the summit of the supraoccipital is greatly expanded and again much contracted midway between the top and the condyles, and on either side of the median line is a long and narrow excavation, which is not present in the American forms. Another similarity to *Sus*, and also to some extent to *Hippopotamus*, is seen on the superior border of the foramen magnum, where the continuation of the supraoccipital sends down two blunt projections, which impart an irregular upper border to the foramen. This latter feature does not appear in the American forms.

The mandible is much elongated to conform with the extremely long muzzle. The horizontal ramus is, as in the Oligocene forms, nearly straight, and is characterized by considerable depth and thickness. The inferior border has one large knob-like tubercle in the middle region beneath $P_{\overline{4}}$ and $M_{\overline{1}}$, and only a trace of a tubercle opposite the posterior face of the symphysis. The angle is also extended below the horizontal line of the inferior border, but not to the extent seen in some earlier forms. These knob-like processes which are given off from the ventral border of the mandible are proportionally small, especially the anterior pair, when

compared with some of the large species (*Pelonax ramosum*) from the upper Oligocene. In the latter form these knobs on the lower jaws are particularly long and heavy, indicating with other peculiarities a diverging line at that time. In *Dinohyus* the alveolar border has a rapid outward turn at the canine to accommodate the enormous root of that tooth. The chin is square and the symphysis shows no mark of division between the two rami. There are two mental foramina: the anterior, which is the larger, is situated below P^1; and the posterior below $P_{\overline{2}}$. The ascending rami are low and rapidly flare outward in order to meet the widely separated glenoid cavities of the squamosals, which is a peculiarity most nearly approaching what is observed in *Hippopotamus*. The condyles are greatly convex antero-posteriorly and their transverse diameter is considerable; they are only very slightly elevated above the alveolar border. The coronoid process is low, but broad, and its free end terminates in an enlarged truncated rugosity. The temporal fossa is deep and extends across nearly the entire antero-posterior face of the ascending ramus, but does not reach very low; its inferior border is developed into a heavy ridge, which unites with the base of the condyle externally. The dental foramen is of rather small size and is a little posterior to the middle antero-posterior diameter of the sigmoid notch and on a level with the alveolar border.

The hyoidean arch of *Dinohyus hollandi* is represented by a number of fragments and three very nearly complete bones, the stylohyoid and both ceratohyals.

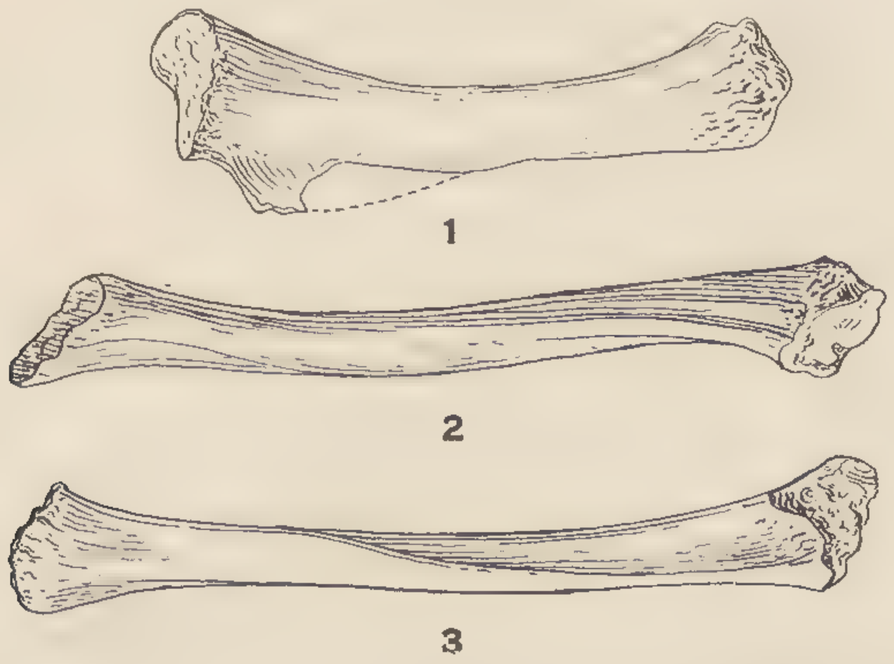


FIG. 34. (1) Inner View of Right Ceratohyal; (2) Inner View of Stylohyal; (3) External View of Stylohyal. Belonging to type of *D. hollandi* Peterson. Nat. Size. (Carn. Mus. Cat. Vert. Foss., No. 1594.)

The different bones appear to be of somewhat smaller proportions than in *Archæotherium ingens* described by Professor Scott. The shaft of the stylohyoid is a sinuous rod with prominent and spiral ridges (of which one extends the entire length of the

shaft) and expanded upper and lower ends. The upper half of the shaft is trihedral in cross-section, while the lower half is subcylindrical. In *Archæotherium*, according to Scott (**87,** p. 286), the upper portion of the shaft is compressed laterally and has a more oval section lower down. The cerato-hyal is shorter than the stylohyoid in about the same proportion as in *Archæotherium*. The proximal end is expanded and cup-shaped, and immediately below the enlarged end the shaft becomes quite thin transversely, but broad antero-posteriorly. The lower half of the shaft is still more oval in section and terminates in an enlarged end for cartilaginous attachments. The bone as a whole is very like that in *Archæotherium*.

MEASUREMENTS.

	Mm.
Greatest length of skull	883
Distance from postorbital process of jugal to and including premaxillaries	528
" " " " " " " " " occipital condyle	305
Length of alveolar border of maxillary and premaxillary	465
Distance from median incisor to M^1	330
Greatest transverse diameter of condyles	165
Vertical diameter of condyle	56
Greatest transverse diameter of skull, approximately	580
Transverse diameter of muzzle in front of orbits, approximately	175
" " " " at P^2	132
Greatest length of mandible	725
Depth of mandible, inferior border of angle to and including condyle	200
" " " at M_3	120
" " " " P_2	100

VERTEBRAL COLUMN.

Atlas. — The atlas, on the whole, is very similar to that of the Oligocene genus. The more important differences are here given. The posterior exit of the vertebrarterial canal is shifted lower down on the posterior face of the transverse process than in *Archæotherium*. In the latter genus the position of this foramen is higher up, or, nearly on the superior face at the base of the transverse process.[38] In *Dinohyus* the facets for the axis are relatively higher and narrower, the cavities for the occipital condyles shallower, the neural canal narrower, and the neural spine somewhat more prominent than in *Archæotherium*. The transverse process does not project backward nearly as much as in the Princeton specimen, and consequently gives to the atlas of the latter a relatively greater total antero-posterior diameter.

Axis. — The axis of *Dinohyus* differs from that of *Archæotherium* in having the

[38] In a specimen (No. 1665) of the Carnegie Museum collection, from the *Titanotherium* beds, Sand Creek, Sioux Co., Nebraska, this foramen is placed lower down than in the Princeton specimen.

articular facets for the atlas more wedge-shaped; the facets are also of relatively less transverse and greater vertical[39] diameter, and the transverse process is heavier. This enlargement of the transverse process is especially noticeable at the superior

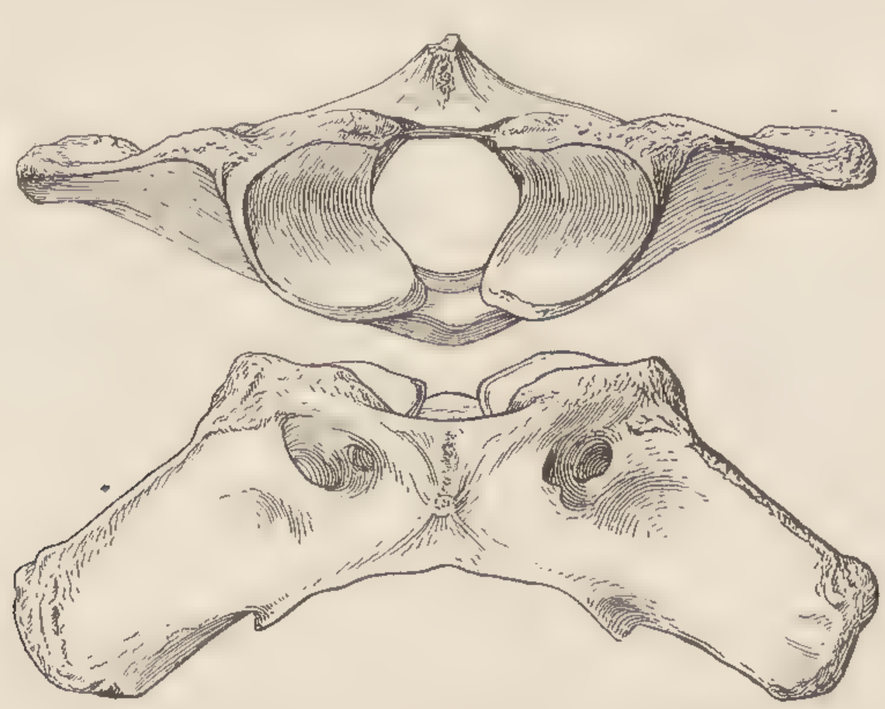


FIG. 35. Anterior and Superior Views of Atlas of *D. hollandi* Peterson. ¼ nat. size.

base over the posterior exit of the vertebrarterial canal where there is a blunt and rugose tubercle. The well defined ridge, which extends backward from the odontoid process along the floor of the neural canal in *Archæotherium*, is in *Dinohyus*

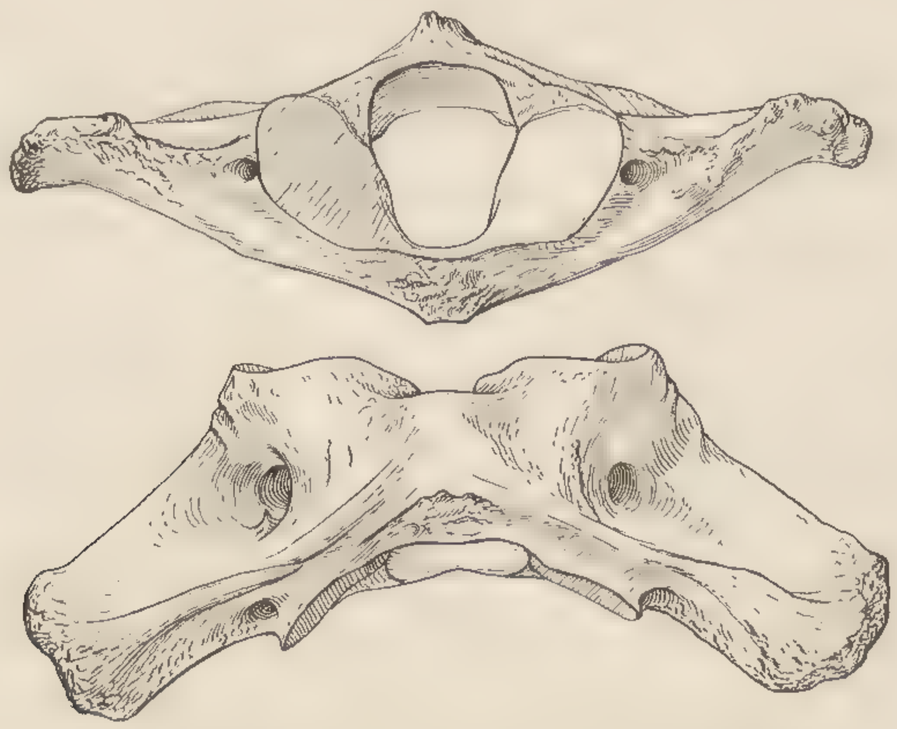


FIG. 36. Posterior and Inferior Views of Atlas of *D. hollandi* Peterson. ¼ nat. size.

converted into a broad rounded surface, which slopes backward and is interrupted by a rough ridge, which extends across the entire floor of the neural canal some

[39] The vertical diameter seems to have developed superiorly, as the ventral projection is of about the same proportion as in *Archæotherium*.

distance back of the odontoid process. Back of this ridge is a transverse excavation, 8 or 10 mm. in antero-posterior diameter, which is again succeeded by an elevated area along the posterior portion of the floor of the neural canal. As in

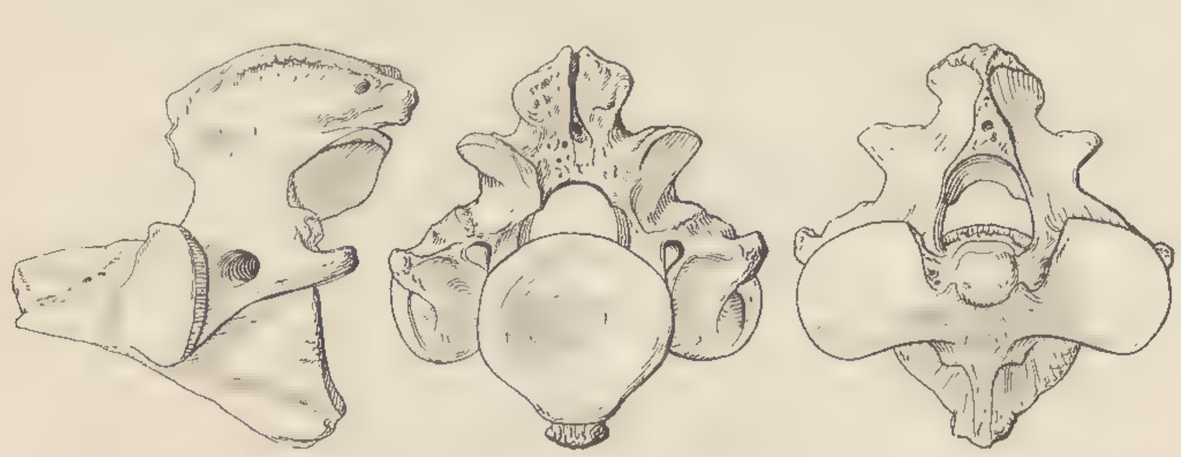


FIG. 37. Lateral, Posterior, and Anterior Views of Axis of *D. hollandi*. ¼ nat. size.

Archæotherium, the pedicles of the neural arches are not pierced by foramina for the passage of the second pair of spinal nerves. These canals are more lateral and are bridged over superiorly by heavy arms of the transverse processes which unite with the sides of the pedicles.

Third Cervical. — The third cervical vertebra differs from that in *Archæotherium* (**87,** p. 290) by having a proportionally much less developed neural spine, a sharper inferior keel, and the bony bridge, which bounds the vertebrarterial canal externally,

FIG. 38. Lateral View of Third Cervical of *D. hollandi* Peterson. ¼ nat. size.

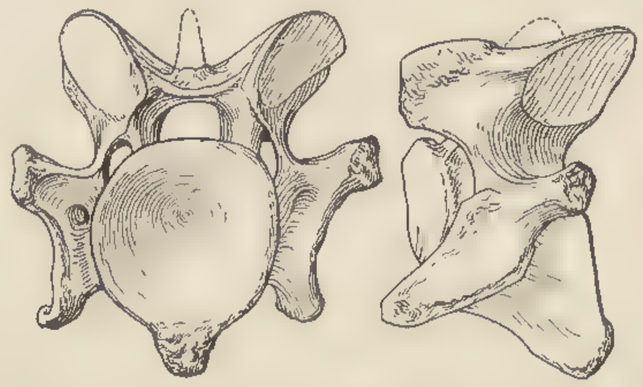


FIG. 39. Posterior and Lateral Views of Fourth Cervical of *D. hollandi* Peterson. ¼ nat. size.

narrower. As Professor Scott has stated (*l. c.*, p. 290) in connection with his study of *Archæotherium*, there are no foramina for the spinal nerve through the anterior portion of the pedicles as in *Sus*.

Fourth Cervical. — The neural spine of this vertebra is damaged, but I infer that, as in the preceding vertebra, it is relatively less developed than in the Oligocene genus. The inferior lamella has a slightly different shape, being more decidedly separated from the diapophysial process and is less developed than in *Archæotherium* (**87,** p. 290). In *Dinohyus* there are deep excavations on the inferior side

of the base of the diapophyses, which are scarcely indicated in the Princeton specimen. The diapophyses are fully as well developed as in *Archæotherium*, and the inferior keel is sharper than in the latter genus.

Fifth Cervical. — As in the preceding vertebra, the neural spine is lost. The centrum is relatively much more opisthocœlous, and the inferior lamella is slightly less developed and less everted than in *Archæotherium*. The inferior keel is sharp

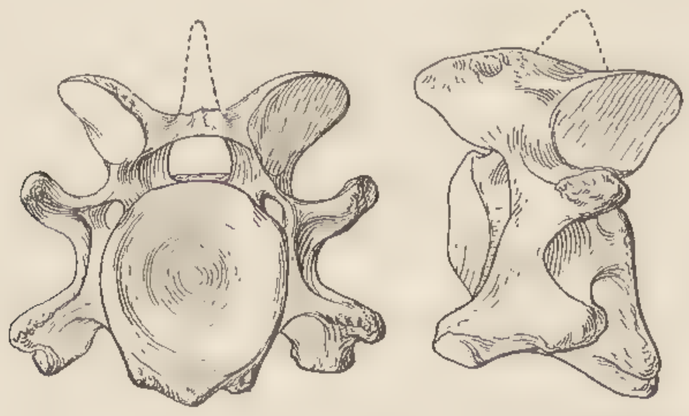


FIG 40. Posterior and Lateral Views of Fifth Cervical of *D. hollandi* Peterson. ¼ nat. size.

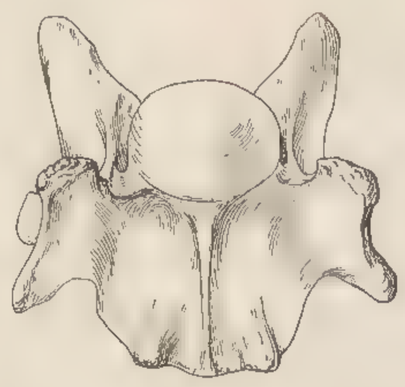


FIG. 41. Inferior View of Fifth Cervical of *D. hollandi* Peterson. ¼ nat. size.

and continues to the postero-inferior border of the centrum, where a blunt tubercle is located on either side of the median keel. In *Archæotherium* the keel is heavier and it terminates posteriorly in a heavy rugose mass, which indicates a relatively

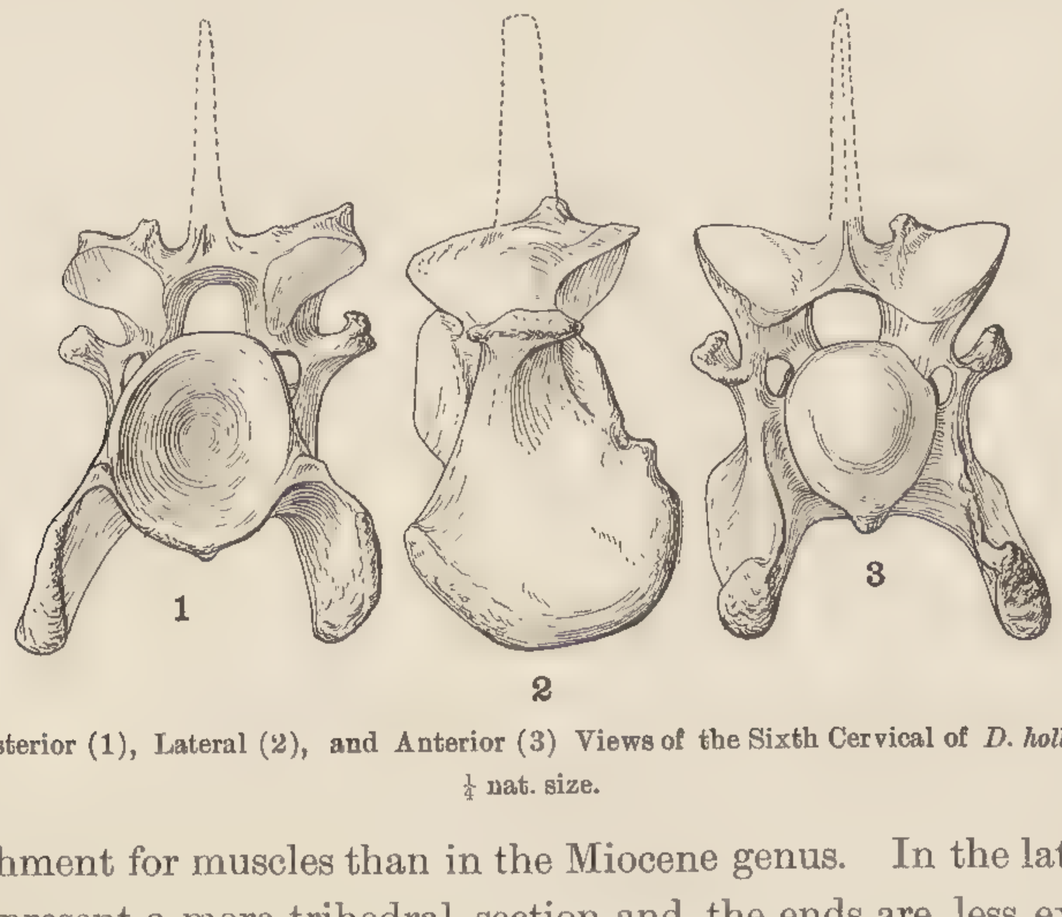


FIG. 42. Posterior (1), Lateral (2), and Anterior (3) Views of the Sixth Cervical of *D. hollandi* Peterson. ¼ nat. size.

heavier attachment for muscles than in the Miocene genus. In the latter genus the diapophyses present a more trihedral section and the ends are less expanded than in *Archæotherium*.

Sixth Cervical. — The base of the neural spine of the sixth cervical vertebra is present, and the size indicates a proportionally less developed process than is the case in the corresponding bone in *Archæotherium.* As in the preceding vertebra, the centrum is relatively more opisthocœlous than in the sixth cervical of the Princeton specimen. The inferior keel is also sharper and terminates in front in a swollen area. The anterior face of the centrum extends down over this area, which adds to the convexity of the centrum in a peculiar manner, quite unusual in most of the Artiodactyla, and is not unlike what is seen in the recent horse. The diapophyses are of about the same proportionate size as in *Archæotherium,* but the inferior lamellæ are relatively more developed, which is remarkable when one bears in mind that the neural spine is relatively less developed, while the neural arch has about the same proportions in both genera.

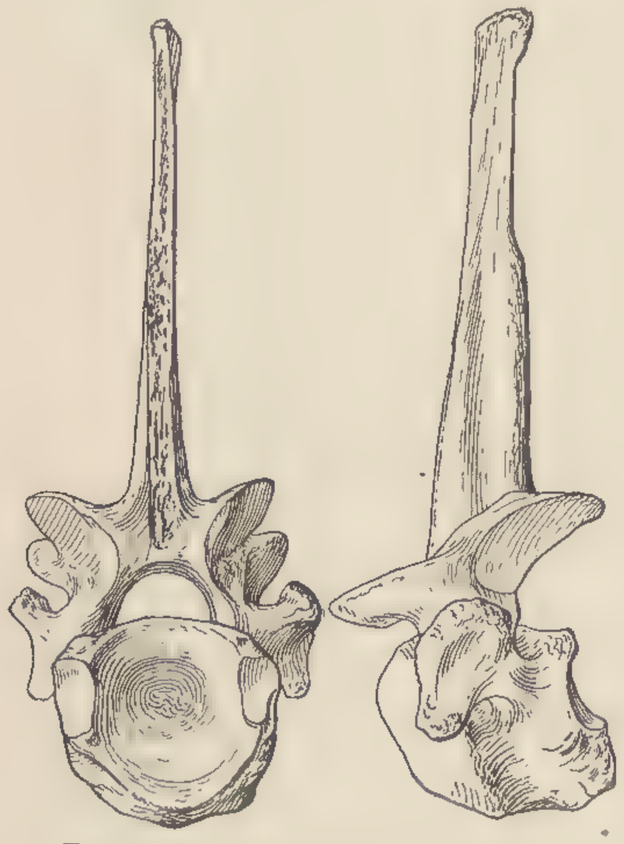


FIG. 43. Posterior and Lateral Views of the Seventh Cervical of *D. hollandi* Peterson. ¼ nat. size.

Seventh Cervical. — As in the preceding vertebræ the neural spine of the seventh cervical vertebra of *Dinohyus* is relatively smaller than in *Archæotherium.* The postzygapophysis is placed higher up than in *Archæotherium,* but is less concave and looks outward more decidedly than in the Oligocene genus. The pedicle is more rounded and the postero-inferior portion of the centrum is proportionally somewhat heavier, and has decided tubercles on either side of the median line, which are absent in *Archæotherium.* The transverse process has the same proportions as in the Princeton specimen, and, as in that specimen, is not perforated by the vertebrarterial canal.

FIG. 44. Inferior View of Seventh Cervical of *D. hollandi* Peterson. ¼ nat. size.

First Dorsal Vertebra. — In the type of *Dinohyus hollandi* there are fourteen dorsal vertebræ which were found in the quarry articulated with one another by their zygapophyses. The first dorsal vertebra is characterized by a long and very heavy neural spine greatly exceeding in length that of the seventh cervical. The neural spine has about the same relative size as in the Princeton specimen, but the postzygapophysis is more distinctly separated from the transverse process by a constricted area, and the centrum is

more opisthocœlous. This vertebra is, except in these minor details, quite similar to the corresponding bone in *Archæotherium*.

Second Dorsal Vertebra.—The neural spine of the second dorsal vertebra is higher than that of the first, but not nearly so robust. In relative proportions the spine agrees quite well with that of *Archæotherium*. The vertebra as a whole

FIG. 45. Lateral and Posterior Views of First Dorsal of *D. hollandi* Peterson. ¼ nat. size.

FIG. 46. Lateral View of Second Dorsal of *D. hollandi* Peterson. ½ nat. size.

FIG. 47. Lateral View of Third Dorsal of *D. hollandi* Peterson. ¼ nat. size.

differs in some important particulars from that of *Archæotherium*, viz.: the vertical diameter of the centrum is relatively greater, owing to the unusual development of the inferior keel; the anterior half of the keel is developed into a heavy and rugose tubercle, which projects well below the anterior face of the centrum; the prezygapophyses nearly meet in the median line, forming a narrow irregular emargination, while in *Archæotherium* they are more widely separated. The posterior face of the

centrum is decidedly more concave than in the Oligocene genus. The general outline of the bone, except in the matter of its deeper centrum, is quite similar to that of the Princeton specimen.

Third Dorsal Vertebra.—The tip of the spine of the third dorsal is broken off, but it was evidently as high as that of its predecessor, and only slightly lighter.

FIG. 48. Lateral View of Fourth Dorsal of *D. hollandi* Peterson. ¼ nat. size.

FIG. 49. Lateral View of Fifth Dorsal of *D. hollandi* Peterson. ¼ nat. size.

One of the most important differences between the vertebral column of *Dinohyus* and that of *Archæotherium* is seen in the arrangement of the canals through the sides of the pedicles and the vertical canals through the superior portion of the neural arch, similar to that in *Sus* and *Bison americanus*. In Professor Scott's admirable memoir (**87,** p. 290) it is stated that the pedicles of the neural arch are not perforated by vertical canals as in *Sus*. While this is to a certain extent true, it is seen upon very close scrutiny of the specimen, that some of the dorsals have the vertical as well as the transverse canals present, although they are relatively smaller, are more irregular in their position, and could not have possessed the functional

importance which they have in the Miocene genus. Back of the second dorsal in *Dinohyus hollandi* the arrangement of these canals is almost identical with that in *Sus*, the vertical canal being even relatively larger.

The costo-vertebral canals are very narrow but deep excavations, which lead directly into these large horizontal and vertical canals, forming an excellent protection for the spinal nerves. The keel of the centrum is fully as well developed as in the preceding vertebra. In *Archæotherium* the corresponding vertebra has a heavy and rugose area on the anterior half of the keel, but the ventral projection is not nearly so great.

Fourth Dorsal Vertebra. — In *Dinohyus* this vertebra is more nearly like that of the *Archæotherium* skeleton from Princeton than any of the preceding dorsals. The vertical diameter of the centra back of the second dorsal in *Archæotherium* rapidly increases, so that the centrum of the fourth has about the same proportionate diameter as in *Dinohyus*. The arrangement of the foramina through the walls of the neural canal, which are sometimes absent in *Archæotherium ingens*, is the chief character showing a difference between the vertebræ of the two animals.

Fifth Dorsal Vertebra. — The top of the neural spine of the fifth dorsal is complete, but unfortunately the contact is lost at the lower half of the spine. The length of the spine is estimated by a gradual slope from the second to the seventh dorsal vertebræ, which have complete neural spines. The general construction of this bone differs so little from that in *Archæotherium* that a description seems hardly necessary.[40]

Sixth and Seventh Dorsal Vertebræ. — With the exception of the broader and undoubtedly longer neural spine in the sixth dorsal vertebra, the seventh differs very little from it, and the two are so similar to the fifth dorsal that a separate description seems superfluous in this connection. With the exception of the perforations of the transverse processes, the deep median furrow near the base and rugose surfaces on the anterior faces of the neural spines, and the somewhat more sharply keeled centra, there are no differences from the corresponding vertebræ in *Archæotherium* described by Professor Scott.

Eighth Dorsal Vertebra. — This vertebra has no ventral keel on the centrum, it being quite smoothly rounded below, and consequently having a smaller vertical depth than the vertebræ anterior to it. The median furrow or groove on the anterior face of the neural spine extends well up and is still quite deep on the fragment we possess, proving that the spine itself must have attained a consider-

[40] In cleaning off the matrix for a closer examination of the transverse process of the fifth dorsal vertebra in *Archæotherium ingens*, which Professor Scott described, it is found that there is a small foramen on the upper face of the neural arch which is apparently connected with the horizontal canal as in *Sus*.

able length. The tubercular facet for the rib is of large size and concave in the antero-posterior direction. The transverse process is heavy, as is also the upper portion of the neural arch. The pedicle and transverse processes are perforated by the canals referred to above.

Ninth Dorsal Vertebra. — The ninth dorsal is represented only by a portion of the neural spine, half of the neural arch, and the upper third of the centrum of

FIG. 50. Lateral View of Sixth Dorsal of *D. hollandi* Peterson. ¼ nat. size.

FIG. 51. Lateral View of Seventh Dorsal of *D. hollandi* Peterson. ¼ nat. size.

FIG. 52. Lateral View of Eighth Dorsal of *D. hollandi* Peterson. ¼ nat. size.

the left side. The capitular and tubercular facets are only slightly smaller than in the preceding vertebræ. The transverse process is of about the same size, but the perforations are somewhat smaller than in the eighth dorsal vertebra.

Tenth, Eleventh, and Twelfth Dorsal Vertebræ. — The tenth, eleventh, and twelfth dorsal vertebræ are represented only by fragments, but enough remains to supply essential characters. The centra are depressed and apparently have no ventral keels, and the neural spines still continue to have the median groove which extends from the base upward for some distance on the anterior face of the spines. On the tenth dorsal the rib-facets possess considerable size, but they rapidly diminish in the following vertebræ. The neural spines also show a rapid reduction, but the perfo-

rations of the pedicle and transverse processes continue to be of large size up to the thirteenth dorsal. There is only a slight suggestion of the metapophysis on the twelfth dorsal vertebra.

Thirteenth Dorsal Vertebra. — In the region of the thirteenth dorsal there is an important change in the dorsal series. The neural spine was still, no doubt, of the dorsal type, but short. The anterior zygapophysis is also of the dorsal type, while the postzygapophysis fits into a nearly typical lumbar articulation of the succeeding vertebra. The transverse process is quite heavy and has an almost flat surface for the tuberculum of the rib. The metapophysial area is divided into three small tubercles and the superior aspect of the transverse process is on the whole very rugose. The vertical perforation is very small and is placed near the anterior margin of the neural arch. The horizontal canal for the transmission of the spinal nerves, which perforates the wall of the neural arch between the posterior capitular and the tubercular facets is of large size. This vertebra appears to correspond most closely with the vertebra described by Professor Scott as the eleventh thoracic vertebra in *Archæotherium ingens* (**87,** p. 293).

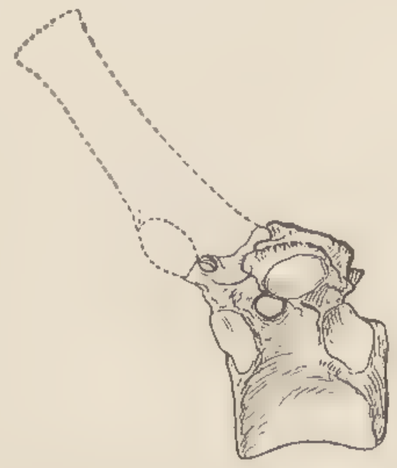


FIG. 53. Lateral View of Thirteenth Dorsal of *D. hollandi* Peterson. ¼ nat. size.

Fourteenth Dorsal Vertebra. — The fourteenth dorsal of *Dinohyus* agrees most closely with the one which Professor Scott regards as the twelfth of *Archæotherium ingens.* In *Dinohyus* this vertebra differs in many important characters from either the twelfth or thirteenth dorsals in the Princeton specimen in which the thirteenth is the last dorsal according to Scott. From both the twelfth and the thirteenth in the latter specimen the fourteenth thoracic vertebra in *Dinohyus* differs in having a very well developed transverse process, a large perforation through the sides of the neural arch back of the capitular facet for the last rib, and the absence of anapophyses. The superior portion of the neural spine is broken off, but its broad antero-posterior aspect indicates that in shape it closely resembled the lumbar vertebræ. The posterior zygapophysis is identical in form with that of the twelfth (thirteenth ?)[41] in *Archæotherium.* As Scott has shown in his memoir, page 293, the cross-section of the zygapophyses of the lumbar vertebræ present an S-like outline which causes the development of large episphenial processes. The neural canal is transversely broad, but low. The centrum is well rounded and has no ventral keel or prominent rugosities for muscular attachments. The facet for the last rib is of large size, oval in

[41] The writer is of the opinion that *Archæotherium* from the Oligocene may have had fourteen thoracic (dorsal) vertebræ thus agreeing in its vertebral formula with *Dinohyus.*

outline, and placed in an oblique position. The metapophyses are prominent on this vertebra.

Lumbar Vertebræ.—There are only four lumbar vertebræ represented in the type specimen of *Dinohyus*, but from the fragments at hand it is very plainly shown that the last lumbar has been lost.[42] There are in the splendidly preserved speci-

FIG. 54. Anterior, Inferior, and Lateral Views of Fourteenth Dorsal of *D. hollandi* Peterson. ¼ nat. size.

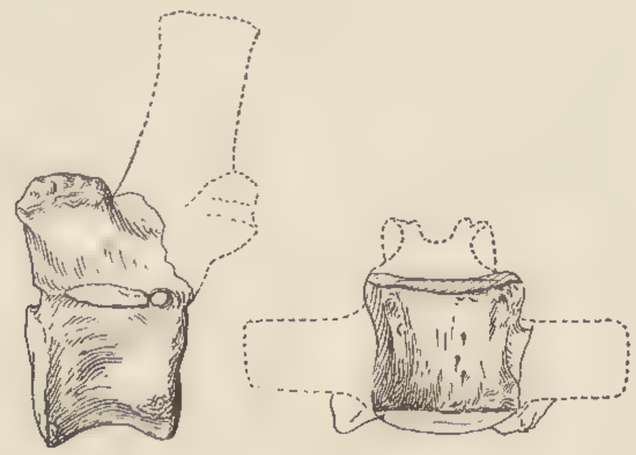


FIG. 55. Lateral and Inferior Views of First Lumbar of *D. hollandi* Peterson. ¼ nat. size.

men of *Archæotherium* in the Princeton collection, six lumbar vertebræ, which undoubtedly also must have been the number in the genus *Dinohyus*. This arrangement is thought to be correct in view of the evidence at hand from the Miocene and Oligocene genera and also from the fact that in *Sus scrofa* and the *Pecora* there are sometimes twenty thoraco-lumbar vertebræ: fourteen dorsals and six lumbars.

FIG. 56. Lateral View of Second Lumbar of *D. hollandi* Peterson. ¼ nat. size.

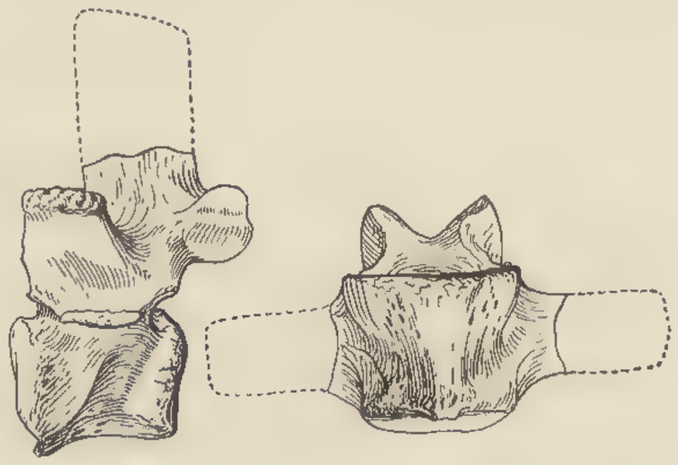


FIG. 57. Lateral and Inferior Views of Third Lumbar of *D. hollandi* Peterson. ¼ nat. size.

The centra of the four lumbar vertebræ preserved in the type are all present and in two instances portions of the arches and of the zygapophyses are also present. The neural spines and the transverse processes were unfortunately all lost in the proc-

[42] In the spring of 1905, the fragments of the lumbar vertebræ, the sacrum and a portion of the pubic symphysis of the pelvis was found by the writer on the edge of the quarry. These parts were dug out during the excavation in quarry No. 1, in the fall of 1904, by Mr. Cook and his assistants.

ess of collecting.[43] The neural spines are, however, restored from another specimen (No. 2193B) collected in the Agate Spring Quarries (Quarry No. 1) in 1908 and their shape (see Plates LX, LXI) is thought to be nearly correct. The centra in the anterior portion of the series are somewhat different from those in *Archæotherium*, having a transversely broader aspect ventrally and a very rugose surface on the sides. Posteriorly the centra become more depressed and the rugosities on the sides are divided into an anterior and a posterior area by a decidedly broad and shallow groove, extending obliquely from the posterior intervertebral notch to the ventral portion of the centrum, where it fades away, leaving a sharp ridge on the anterior margin of the exit of the groove. The neural arch of the first lumbar vertebra is pierced by a canal immediately posterior to the base of the transverse process. On the second lumbar is a similar canal on the right, while on the left side there is no canal present.

FIG. 58 Inferior View of Fifth Lumbar of *D. hollandi* Peterson. ½ nat. size.

In another specimen (No. 2126, Carn. Mus. Cat. Vert. Foss.) of *Dinohyus hollandi* is a last lumbar vertebra which approximates the proper size of the type specimen. This vertebra presents some interesting differences from the corresponding bone in the Princeton specimen. Of these differences the more important ones are: the proportionately lighter postzygapophyses and the much heavier transverse processes in *Dinohyus;* the enlarged transverse process of the last sacral vertebra in *Dinohyus*, which is due in a great measure to the heavy and rugose posterior border, somewhat after the analogy of some of the *Perissodactyla* (*Equus*). In the last lumbar

FIG. 59. Posterior, Lateral and Anterior Views of Sixth Lumbar of *D. hollandi* Peterson. ½ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2126.)

vertebra of *Archæotherium ingens* the transverse process has in its posterior border near its base a small and rugose tubercle, which apparently had a tendency to meet

[43] A series of four posterior lumbar vertebræ (No. 2139B) was found in quarry No. 1 during the last (1908) season which furnishes some additional information. There were one and most probably two additional lumbar vertebræ in front of this series, judging from the absence of vertebræ with no perforations of the neural arches as in the first and second lumbars of the type and also from the characters of the fourteenth dorsal, which is present in this series.

a corresponding surface on the anterior face of the pleurapophysis of the first sacral vertebra and is somewhat similar to what is found in *Hippopotamus*. The transverse process of the last lumbar vertebra in *Archæotherium* is otherwise quite light, as is the case in all the preceding lumbar vertebræ. In the specimen under description the heavy posterior border of the transverse process of the vertebra does not come in contact with the anterior face of the pleurapophysis of the first sacral, but had a cartilaginous attachment with the ilium. The neural spine has a vertical position and its anterior and posterior borders gradually taper from the base of the spine to the summit. The latter is rounded, slightly enlarged, and rugose. The neural canal is broad, but low, and its floor is occupied in the median line by a heavy ridge, which extends antero-posteriorly the entire length of the superior face of the centrum. The centrum is depressed, but possesses a considerable transverse diameter; its posterior face is larger than its anterior. The prezygapophyses have prominent surfaces for the episphenial processes of the vertebra in advance of it, and these processes of the postzygapophyses are also quite prominent.

Sacrum.—The sacrum is composed of three well coössified vertebræ.[44] The centrum of the first sacral vertebra is quite large, but the succeeding two rapidly

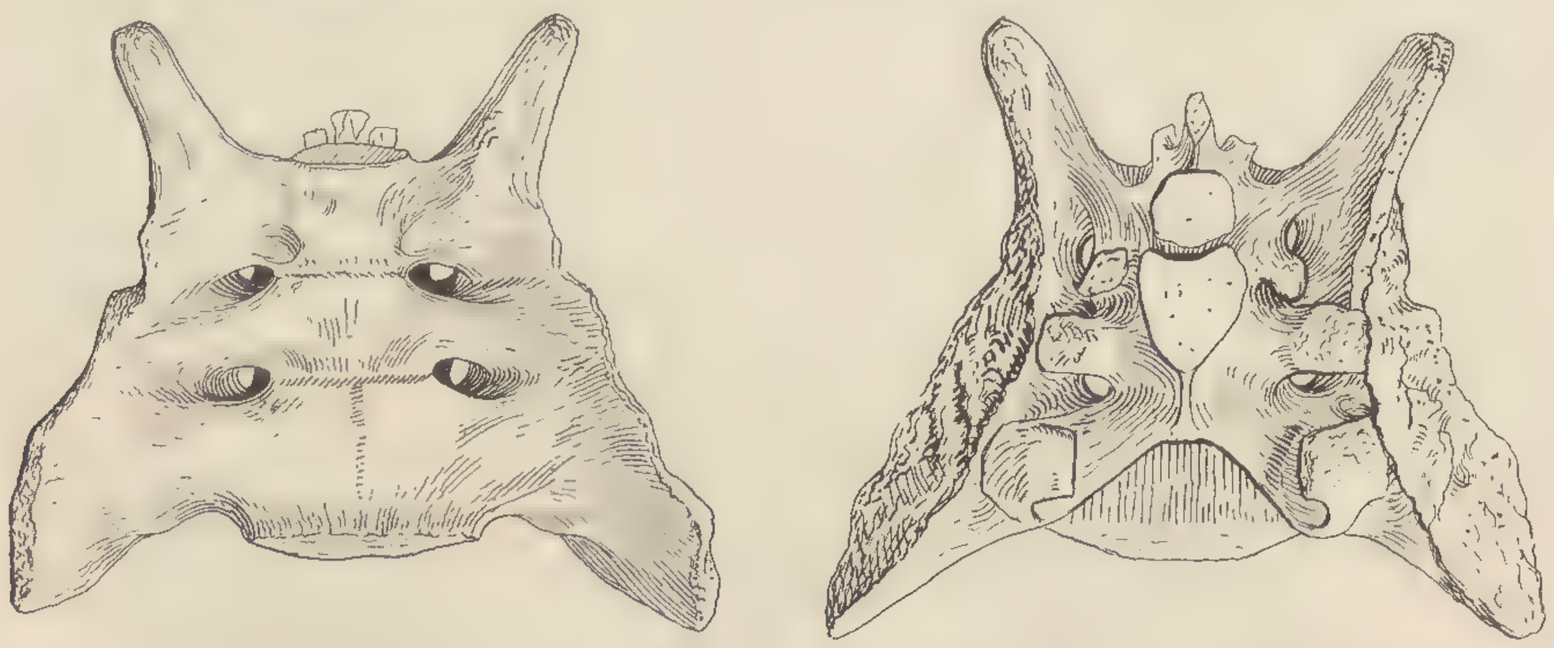


FIG. 60. Inferior and Superior Views of Sacrum of *D. hollandi* Peterson. $\frac{2}{3}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2126.)

decrease in size, so that the posterior face of the centrum of the last vertebra has the transverse diameter less than one half of the anterior face of the first sacral. The pleurapophyses, which are very heavy on the first sacral, decrease in the posterior sacrals as rapidly as the centra. Unfortunately the neural spines are lost,

[44] In examining the sacrum of the Princeton specimen, *Archæotherium ingens*, No. 10885, it is seen that on its ventral face there are three distinct centra, which are very firmly coössified. Professor Scott (87, p. 294) mistook the two posterior centra of this sacrum for one only.

but their bases indicate that they were coössified so as to form one solid spine. The neural canal is of considerable size a nd its outline anteriorly is subtriangular; it diminishes rapidly backward agreeing in its diameter with all the other measurements of the sacrum. The chief differences revealed by the sacrum of *Dinohyus* when compared with that of *Archæotherium* are the relatively smaller antero-posterior and transverse diameters of the centrum, the actual measurements of length and breadth in the former being only very little greater than those of the latter genus, notwithstanding the smaller size of *Archæotherium.* The vertical diameter of the anterior face of the centrum more nearly corresponds to that of the Oligocene genus. The prezygapophyses have, as in *Archæotherium*, the additional articular surfaces for the episphenial processes of the last lumbar vertebra.

From material acquired in 1908 I am able to give complete illustrations (see figs. 60–62) and also to more fully describe parts of the sacrum, which are partially or wholly lost in the type specimen.

The reduced diameter, especially the antero-posterior, of the centra in the sacrum observed in the type specimen of *Dinohyus hollandi* is repeated in other individuals. In No. 2126 (Carn. Mus. Cat. Vert. Foss.) there is a complete sacrum (see figs. 60–62) and its measurements agree quite closely with those of the type.

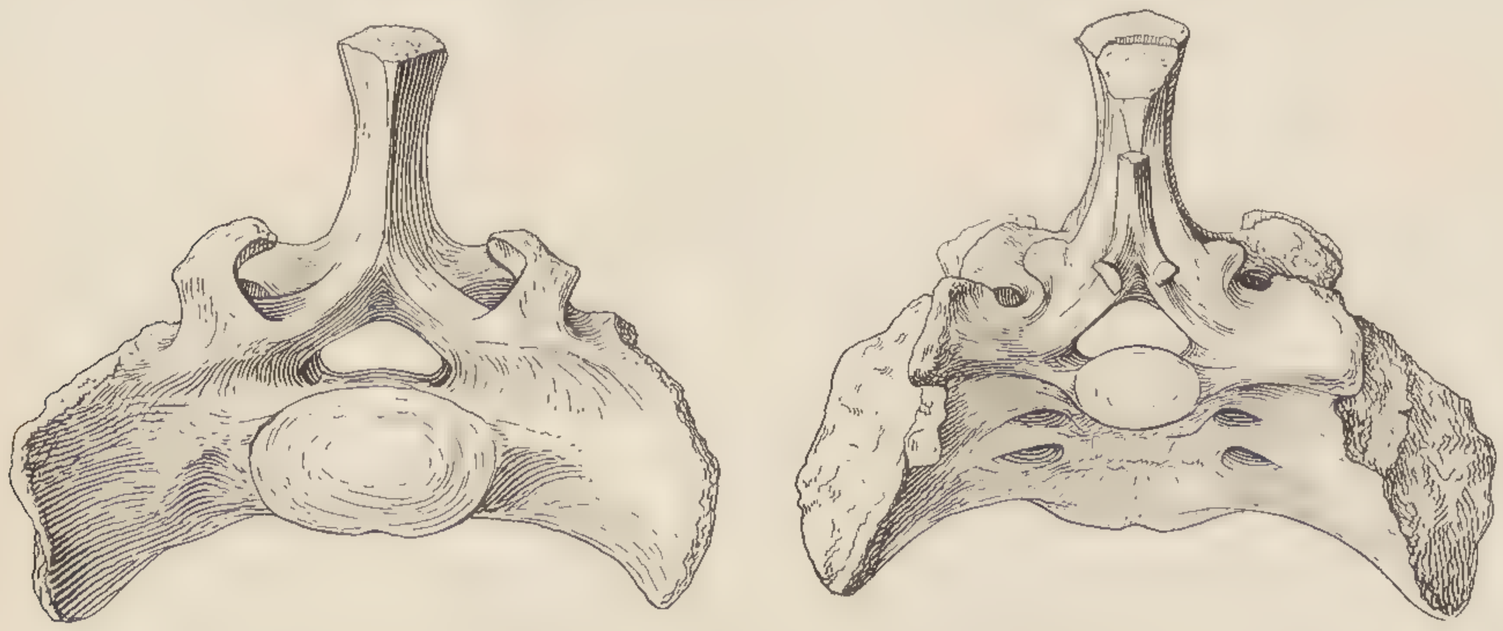


FIG. 61. Anterior and Posterior Views of Sacrum of *D. hollandi* Peterson. $\frac{2}{3}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2126.)

Anteriorly the neural canal, which is triangular in outline, is of large size and rapidly decreases posteriorly. All the sacral foramina are of large size. The two anterior spinous processes are very heavy and quite solidly coössified, except at their extremities,[45] which are slightly separated and also greatly enlarged. The spine of the

[45] In a smaller though older specimen (No. 2139) the summit of the spines is solidly coössified and much expanded laterally.

last sacral vertebra is entirely free from those in front of it and all of its diameters, though of considerable size, are much reduced, when compared with the heavy spines of the first two vertebræ. The postzygapophyses are quite well developed and bear distinct articular facets for the prezygapophyses of the first caudal vertebræ. The posterior extension of the pleurapophyses exhibits a free area back of the iliac con-

FIG. 62. Lateral View of Sacrum of *D. hollandi* Peterson. $\frac{2}{3}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2126.)

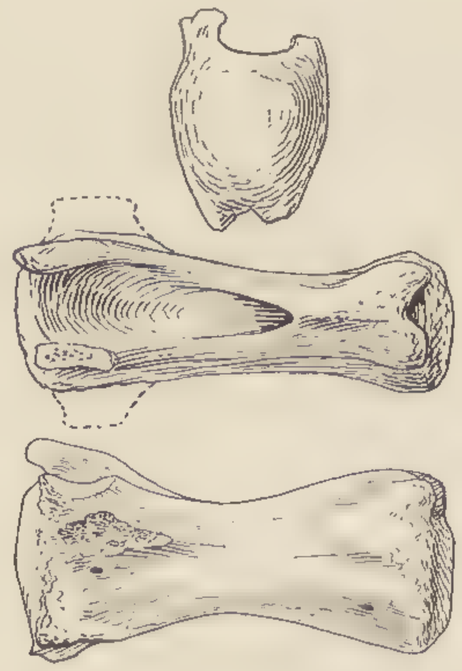


FIG. 63. Anterior, Superior and Inferior Views of Caudal from about the Middle of the Tail of *D. hollandi* Peterson. $\frac{2}{3}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2135.)

FIG. 64. Superior and Lateral Views of Posterior Caudal of *D. hollandi* Peterson. $\frac{2}{3}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 1823.)

tact which is fully as large if not larger than is the case in *Archæotherium ingens* (see fig. 62).

Caudal Vertebræ.— The caudal vertebræ of the type of *Dinohyus* are not present. From several isolated bones found scattered throughout the bone-bearing layer of the quarry and also from a vertebra (No. 2135) found in the same horizon north of the Niobrara River, it is plain that the tail was of practically the same proportionate length as that of the Oligocene genus. Cuts of this bone and of one of the posterior bones of the tail found in quarry No. 1 are here given (figs. 63 and 64).

RIBS.

The ribs on both sides (especially the ones in the anterior portion of the thoracic cavity) are well represented in the type of *Dinohyus hollandi*. The first rib is somewhat sub-cylindrical proximally and broadens almost immediately below the head, while in *Archæotherium ingens* it continues rod-like to a greater distance distally and flares out more suddenly at the ventral end. In the anterior portion of the series

the ribs are broad, with compressed sessile heads, and large tubercles, which are separated from the heads by deep cavities in the same manner as in *Archæotherium*. The fragments of the posterior ribs indicate that they were perhaps proportionately

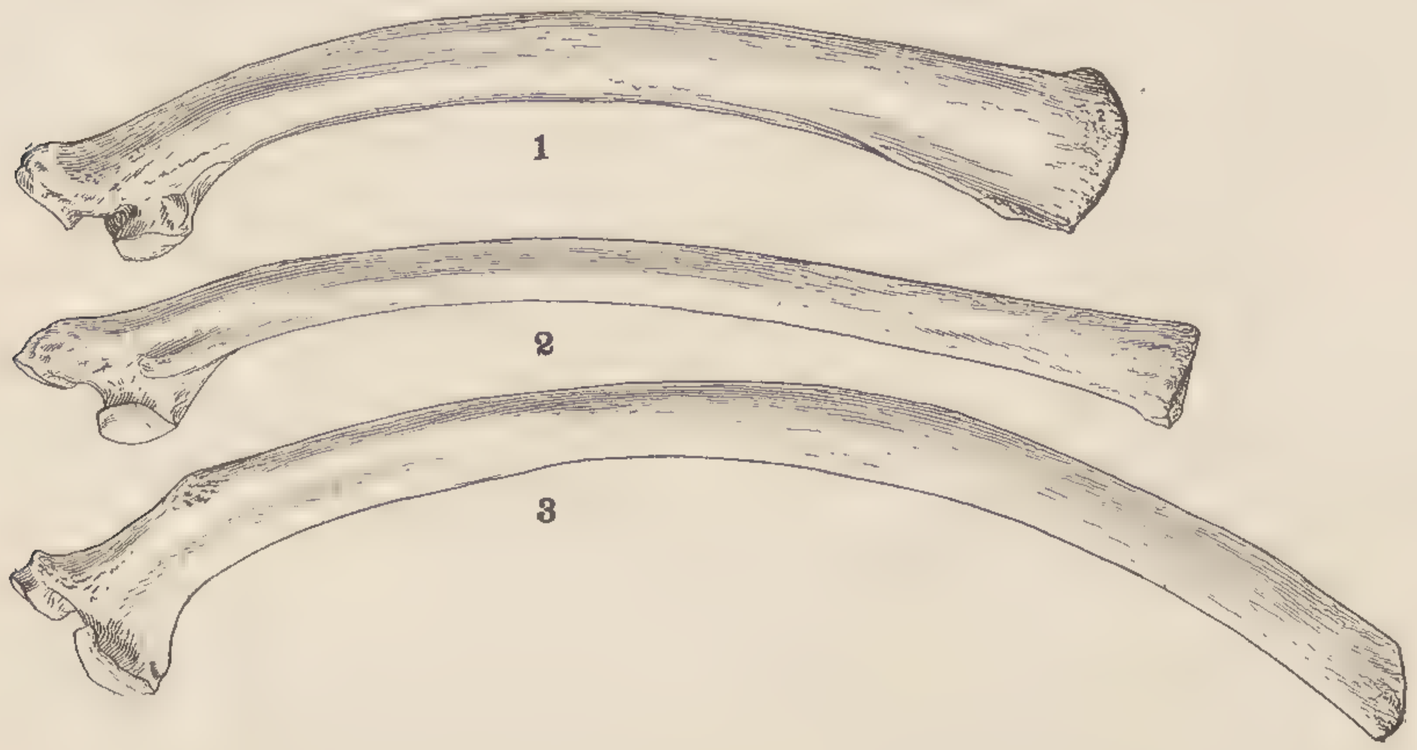


FIG. 65. (1) First Rib; (2) Second Rib; (3) Fifth Rib. From type of *D. hollandi* Peterson. ¼ nat. size.

broader than those in *Archæotherium*. In their relative lengths the ribs are not unlike those of the Oligocene genus, those behind being relatively perhaps somewhat longer.

STERNUM.

There are six sternebræ present in the type. The structure of the sternum is unique and can hardly be compared with that of the Suidæ. The presternum has an unusual vertical diameter, it is compressed transversely and the side view presents an irregular and curious outline.

The superior border of the presternum is slightly concave and terminates in front in a heavy and rugose tubercle; anteriorly the bone is strongly emarginate, producing the superior tubercle which has just been mentioned and an additional, larger, inferior tubercle (see No. 1 in fig. 66). Ventrally the bone again has an emarginate border which terminates posteriorly in a rapidly expanded, truncated, and very rugose process. The contact for the succeeding segment continues, from the truncated process mentioned, obliquely forward and upward and terminates in a slightly enlarged area which forms the contact for the second pair of ribs. The attachments for the first pair of ribs are situated on the lower half of the bone, nearer the anterior than the posterior border. In *Archæotherium ingens* the presternum has the same general outline as in *Dinohyus*, but the borders, especially the

anterior, are less emarginate, which gives to the manubrium of the former genus a less striking appearance.

The first segment of the mesosternum has a curious structure. It is compressed laterally and its vertical is much greater than its antero-posterior diameter. The side view shows a Ω-shaped outline with the straight border behind. The segment is expanded on its borders, those behind being the heaviest. The antero-posterior

FIG. 66. (1) Lateral View of Sternum. (2) Inferior View of Sternum. Type of *D. hollandi* Petersón. ¼ nat. size.

diameter of the bone is slightly greater ventrally than dorsally. The bone differs greatly from that in *Archæotherium ingens* which has a relatively greater diameter vertically and a more angular outline laterally. The following two segments in the sternum of *Dinohyus* are coössified and their vertical diameter rapidly decreases, while their transverse diameter increases. The transverse diameter of the dorsal border is twice that of the ventral, and the posterior face of the fourth segment very suddenly expands laterally. The succeeding two segments of the mesosternum are broader than deep and the last segment is the broadest and shallowest. The dorsal face is considerably broader than the ventral and the last two segments are slightly concave both dorsally and ventrally. The posterior border of the last segment is injured by erosion, but the suture separating the following segment (xiphisternum) is plainly indicated (see fig. 66, No. 2). The sternum as a whole is not unlike that of *Archæotherium*, but it possesses a proportionally smaller antero-posterior diameter, which seems to indicate that the thorax of *Dinohyus* was relatively shorter.

Sternal Ribs. — There were four ossicles found with the sternum which are evidently the sternal ribs. They are much enlarged at one end and taper rapidly to the other (the attachment for the sternum) and have rugose faces for a heavy cartilaginous covering.

MEASUREMENTS.

	Mm.
Atlas, greatest antero-posterior diameter	152
" " transverse "	337
" " vertical diameter including neural spine	127
transverse diameter of articulation for condyle	166
" " " " " " axis	144
Axis, greatest antero-posterior diameter	140
" " transverse "	145
" " vertical diameter including neural spine	160
" length of odontoid process	44
" transverse diameter of centrum posteriorly	78
" vertical " " " "	78
Third cervical, greatest antero-posterior diameter	110
" " transverse diameter	162
" " vertical "	148
" " transverse " of centrum posteriorly	80
" " vertical " " " " including ventral keel	96
Fourth cervical, greatest antero-posterior diameter	105
" " " transverse "	144
" " " vertical " approximately	145
" " transverse diameter of centrum posteriorly	80
" " vertical " " " " including ventral keel	98
Fifth cervical, greatest antero-posterior diameter	105
" " " transverse "	145
" " " vertical " approximately	160
" " transverse diameter of centrum, posteriorly	80
" " vertical " " " "	97
Sixth cervical, greatest antero-posterior diameter	110
" " " transverse " approximately	140
" " " vertical " "	260
" " transverse diameter of centrum posteriorly	76
" " vertical " " " "	88
Seventh cervical, greatest antero-posterior diameter	118
" " " transverse "	125
" " " vertical " including neural spine	318
" " antero-posterior diameter of centrum	86
" " transverse diameter of centrum, posteriorly	91
" " vertical " " " "	82
First dorsal, greatest vertical diameter	480
" " antero-posterior " of centrum	70
" " greatest transverse " " " posteriorly	93
" " vertical diameter of centrum, posteriorly	69
Second dorsal, greatest vertical diameter	512

	Mm.
Second dorsal, antero-posterior diameter of centrum, posteriorly	65
" " greatest transverse " " " "	89
" " vertical diameter of centrum, posteriorly	65
Seventh dorsal, greatest vertical diameter	365
" " antero-posterior " of centrum	67
" " greatest transverse " " " posteriorly	62
" " vertical diameter of centrum, posteriorly	67
First lumbar, antero-posterior diameter at the zygapophyses	90
" " " " " of centrum	65
" " transverse diameter at anterior zygapophyses	98
" " " " of centrum, posteriorly	68
" " vertical " " " "	54
Sacrum, greatest antero-posterior diameter, approximately	150
" antero-posterior diameter of centrum	105
" transverse diameter of centrum, anteriorly	66
" vertical " " " "	42
" transverse " " sacrum, posteriorly	31
" vertical " " " "	22
" greatest transverse diameter of sacrum	165

Ribs.

Greatest length of first rib	430
" " " second rib	467
" " " sixth rib	620
" " " eleventh rib	710
" " " last rib, approximately	540

Sternum.

Greatest antero-posterior diameter	505
" " " " of presternum	172
" vertical " " "	148
" transverse " " " anteriorly	35
" " " " " posteriorly	13
" antero-posterior " " first segment in mesosternum	60
" vertical " " " " " "	112
" transverse " " " " " "	40
Antero-posterior diameter of sixth sternebræ, approximately	90
Transverse " " " "	82
Vertical " " " " approximately	24
Greatest length of largest sternal rib	100
" transverse diameter at largest end of sternal rib	44

The Fore Limb.

The comparative lengths of the different elements of the limbs in *Dinohyus*, when compared with *Archæotherium*, in the judgment of the writer reveal characters

of sufficient importance to warrant, when the many other differences are also taken into account, the generic separation of the two forms. From the very complete description of *Archæotherium ingens* by Professor Scott it is quite plain that the Oligocene genus was already capable of high speed, which appears to have been a requirement of these animals throughout the successive geological ages in which they existed. We naturally look for a reduction in the length of the humerus and femur accompanied by the retention or increase of the length of the lower portions of the limbs among the later survivors of the family. The limbs of *Dinohyus* which fortunately were found with the skeleton, show a greater advance than is found in *Archæotherium ingens*[46] in those characters which are necessary for speed and endurance.

FIG. 67. External View of Right Scapula of Type of *D. hollandi* Peterson. ¼ nat. size.

[46] The philosophy of the increase in length of the lower part of the limb in recent hoofed mammals has been discussed by Dr. Matthew in the Memoirs of the American Museum of Natural History, Vol. I, Part 7, p. 432 (1901).

Scapula. — The scapula of *Dinohyus* is relatively higher than that of the Princeton specimen from the Oligocene. Its neck also has a relatively greater transverse diameter. In other respects very little difference in the general make-up of this bone of the fore limb is shown in the two genera. The pre- and postscapular fossæ are divided by the spine in very nearly the same way in *Dinohyus* and *Archæotherium*, while according to Scott (**87,** p. 298), the John Day form, *Boöchœrus humerosus* Cope, has a much broader blade with the pre- and postscapular fossæ of nearly equal width.

MEASUREMENTS.

	Mm.
Scapula, greatest length	560
" " width	335
" transverse diameter of neck	93
" antero-posterior diameter of glenoid cavity	86
" transverse " " " "	67

Humerus. — The greater tuberosity of the humerus of *Dinohyus* was unfortunately lost in the process of collecting, so that its elevation above the head is only conjectural.[47] The bone is otherwise complete and its length is relatively less than that of *Boöchœrus humerosus* from the John Day formation, and considerably less than that of *Archæotherium.* Indeed the humerus of *Dinohyus* is even proportionately somewhat shorter than is the case in *Bos* and *Equus caballus*, while that of *Archæotherium* is relatively longer than in these two recent genera. The proximal end of the humerus in *Dinohyus* is, as in *Archæotherium*, of great antero-posterior diameter; its transverse diameter, though less than the antero-posterior, is also great, perhaps relatively greater than that in *Archæotherium.* The head is large and takes up a considerable portion of the proximal end. The greater tuberosity is very massive and evidently terminated above in a heavy blunt process, as in other representatives of the family. The lesser or internal tuberosity is unfortunately also damaged, but its anterior border indicates a strong margin which bounded the bicipital groove. The latter is broad and displays a large, smoothly convex tubercle, over which the tendon for the biceps muscle spread. The deltoid ridge is prominent and extends well down on the shaft. The distal end is much expanded, especially transversely, as the supinator ridge and the surfaces for the attachments of the ligaments are well developed. The internal epicondyle which is on the point of disappearance in *Archæotherium* is still smaller in *Dinohyus.* The intercondylar ridge, which is fully as prominent as in *Archæotherium*, is shifted even more outwardly than in that genus, and the trochlea has a more modernized appearance. The ridge which bounds the supratrochlear fossa externally is more prominent than in *Archæotherium;* the differ-

[47] From material recently (1908) acquired in the Agate Spring Fossil Quarries, it is very evident that the dotted lines in Fig. 68 are too high.

ence in the relative depth and size of the supratrochlear, and the anconeal fossæ in the two genera is small.

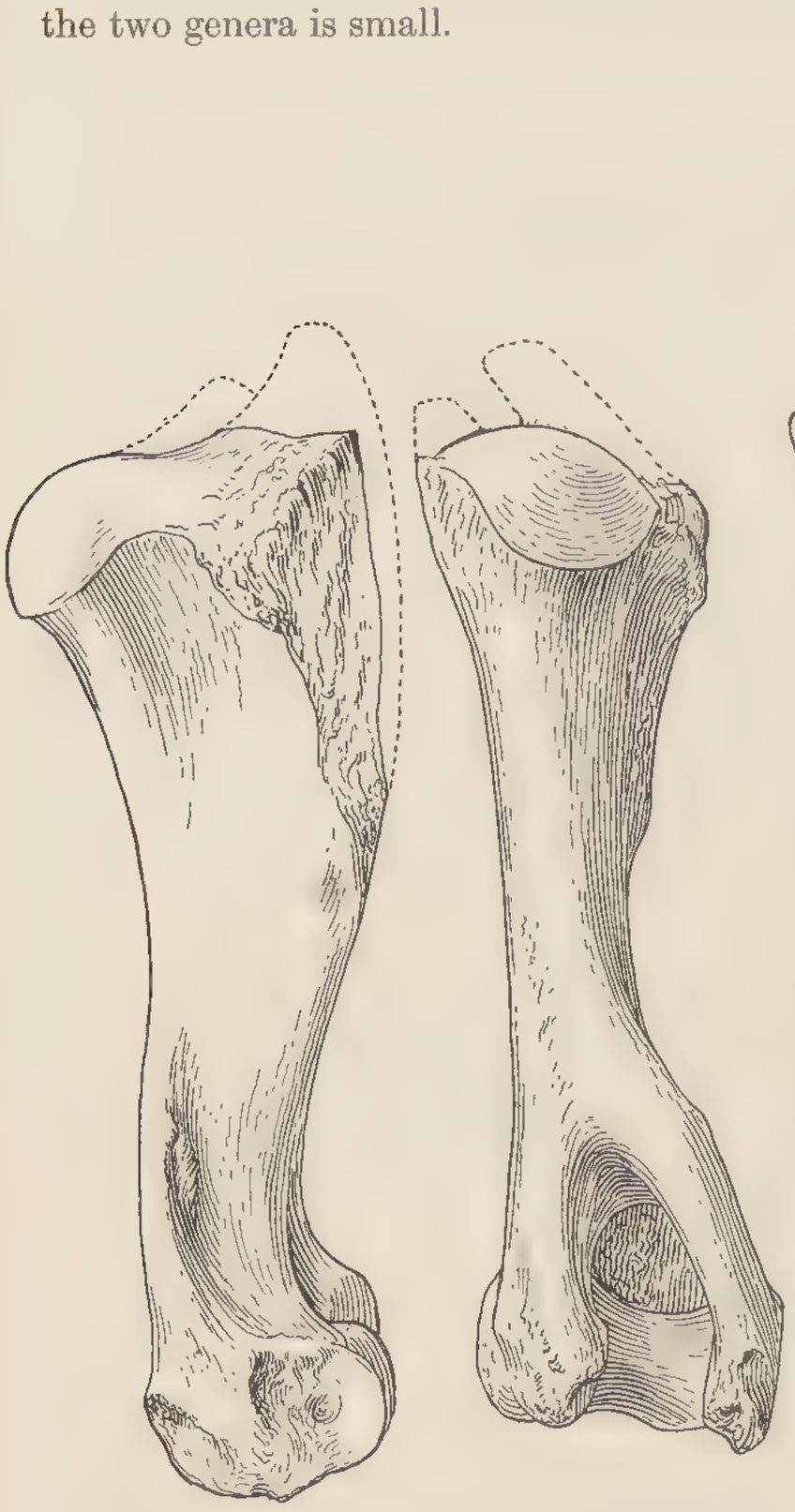


FIG. 68. External and Posterior Views of Humerus of Type of *D. hollandi* Peterson. ¼ nat. size. The dotted lines in the cut are too high.

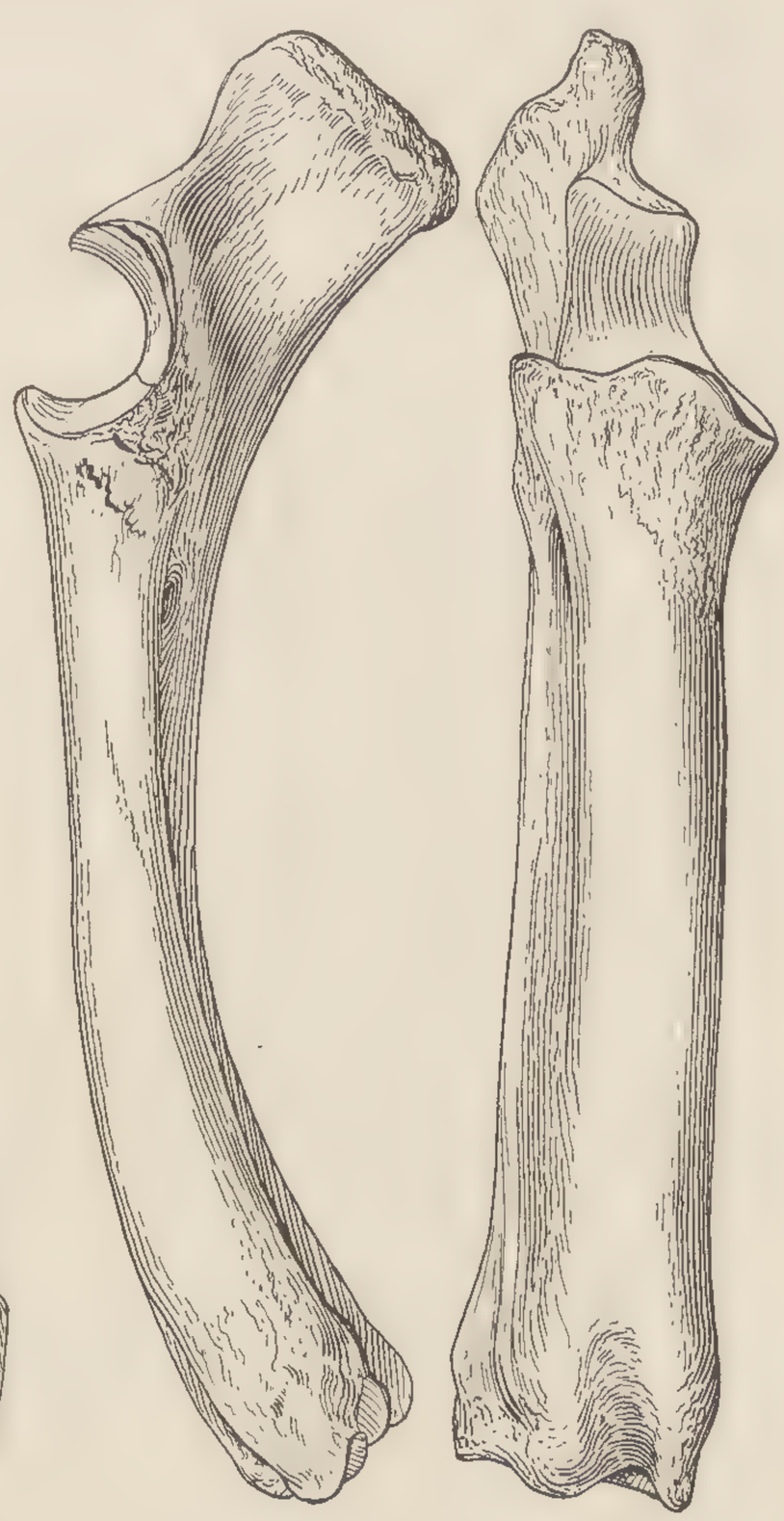


FIG. 69. Radial and Anterior Views of the Ulno-radius of Type of *D. hollandi* Peterson. ¼ nat. size.

MEASUREMENTS.

		Mm
Humerus,	greatest length, approximately	480
"	head of humerus to and including distal end	444
"	middle of head " " " " "	425
"	antero-posterior diameter, proximal end, approximately	175
"	transverse " " " "	120
"	" " distal " "	120
"	antero-posterior " " " "	105

Radius and Ulna. — As has been intimated above, the ulna-radius in *Dinohyus* is proportionately longer than in *Archæotherium ingens*; it is also more curved or bowed forward; the olecranon process is more truncate; and the sulcus for the extensor tendon is less clearly defined. The humeral articulation of the radius differs only in minor details from what is seen in the Princeton specimen. The most noticeable of these minor differences are: the relatively narrower articular surface external to the intertrochlear groove, and a rugose pit, which interrupts the humeral articulation near the posterior margin. The transverse diameter of the shaft of the ulna-radius is shortest immediately below the head; from this point it rapidly increases distally, and the distal extremity has only a slightly greater diameter than the shaft of the compound bone. All traces of the suture between the radius and ulna are practically lost, except at the proximal and distal ends. The deeply channeled external face of the shaft shown in *Archæotherium ingens* is not so noticeable in *Dinohyus*. The ridge which separates the pyramidal and lunar facets is more developed, and the ridge separating the latter facet from that for the scaphoid is less developed than is the case in the Princeton specimen. In this way the peculiar condition found in *Archæotherium ingens* in which the ulna occupies the entire proximal face of the pyramidal and also effects a lateral contact with the lunar is even more emphasized in *Dinohyus hollandi*. The oblique direction of these ridges and the articulating surfaces to receive the carpus are practically nearly the same as in the Oligocene genus. Between the radius and ulna on the posterior face is a deep pit to accommodate the posterior hook-like process on the proximal end of the pyramidal when the manus is flexed backward. This pit is less developed in *Archæotherium*. The pisiform facet in *Dinohyus* as in *Archæotherium* is continuous with that of the pyramidal.

MEASUREMENTS.

	Mm.
Ulna-radius, greatest length	605
" head of radius to distal end	475
" length of olecranon process	157
" transverse diameter of head of radius	105
" " " " shaft immediately below head of radius	76
" greatest transverse diameter of distal end	117
" " antero-posterior diameter of distal end	83

THE MANUS.

Scaphoid. — The scaphoid is not present in the manus of the type specimen of *Dinohyus*. Judging, however, from the proximal articulation of the magnum and the corresponding articulation of the radius, which are quite broad, it is evident

that the scaphoid in the Miocene genus had a relatively greater transverse diameter than in *Archæotherium* from the Oligocene.

In 1908 the Carnegie Museum field party was fortunate in finding (see plan of the quarry, Pl. LIV, Sect. 19, No. 47) a fore foot which was almost completely

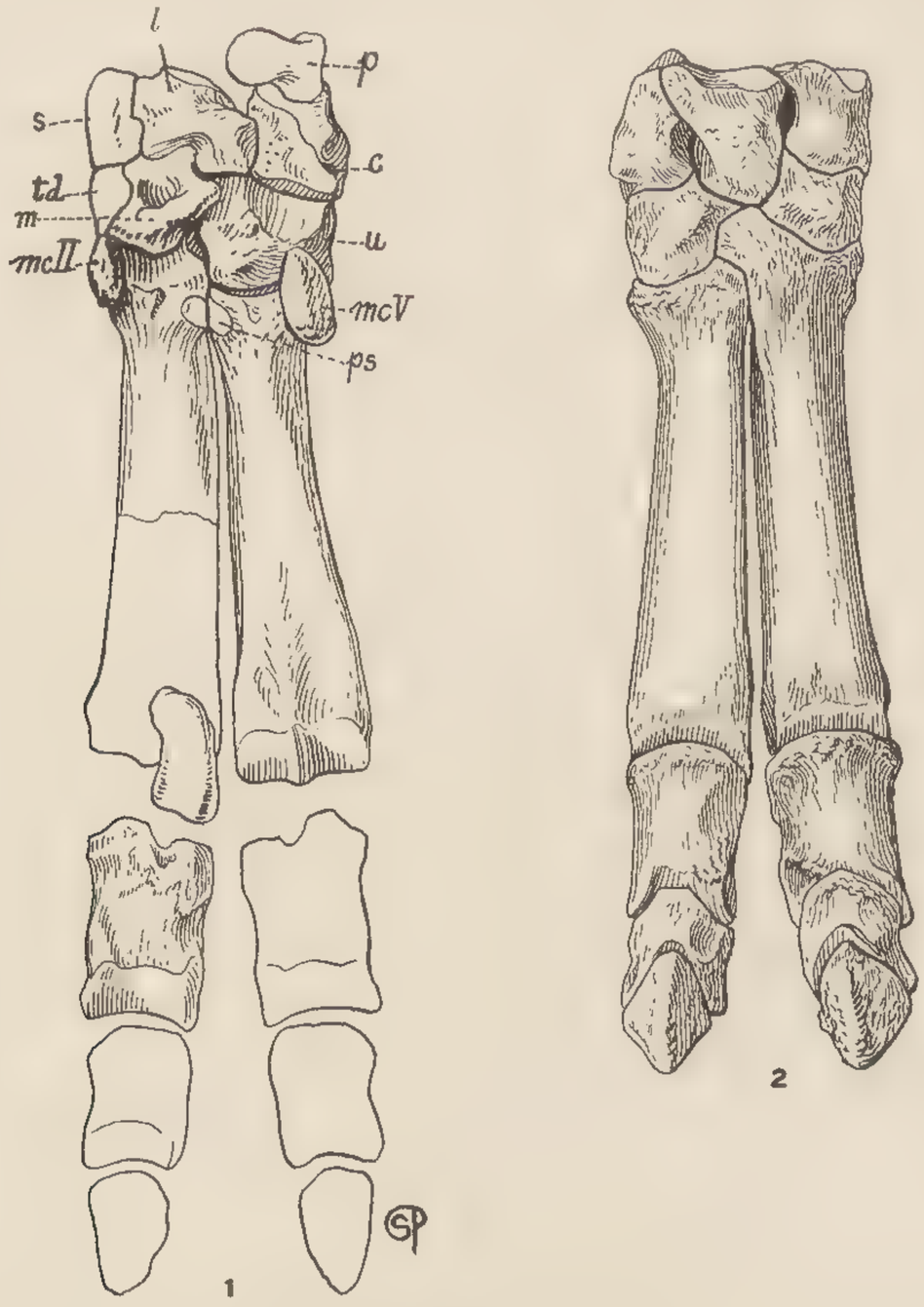


FIG. 70. Posterior (1) and Anterior (2) Views of the Right Fore Foot of Type of *D. hollandi* Peterson. ¼ nat. size. *ps*, facets for palmar sesamoid.

articulated. This specimen (No. 2136, Carn. Mus. Cat. Vert. Foss.) adds materially to our knowledge, inasmuch as the fore foot of the type specimen was found scattered, though in close proximity to the skeleton.

The scaphoid as a whole has a small transverse diameter, while antero-posteriorly it has the greatest diameter of all the carpal bones, which is due chiefly to the large palmar process. The more important characters in which this bone differs from that of *Archæotherium*, described by Professor Scott (**87**, pp. 302–303), are the

relatively greater vertical diameter, the enlarged projection on the dorso-ulnar angle, which causes a slightly greater transverse diameter in this region, and also the absence of the third facet for the lunar on the ulnar face. The articular surface for the radius is divided into two parts, an antero-external and a postero-internal, as in *Archæotherium*. The postero-internal facet is saddle-shaped, concave antero-posteriorly, and constitutes the principal articulating surface of the proximal face. The antero-external facet is small, convex, continuous with the former facet, and descends steeply to conform with the anterior portion of the articular surface on the lunar On the ulnar face of the scaphoid there are two articulating facets for the lunar, one dorsal and one palmar, while in *Archæotherium* there are three. The dorsal facet is located on the prominent point which overhangs the ulnar surface of the radius and articulates posteriorly with the proximal radial face of the lunar by a broader surface than is the case in *Archæotherium*. The lunar facet, which is dorsal and distal in *Archæotherium*, is, as stated above, absent in *Dinohyus*. This facet though small is quite distinct in the former genus, while in *Dinohyus*, the further development of the prominent ridge on the proximal face of the magnum has so effectually separated the scaphoid and lunar in this region that the two bones perhaps very rarely, if ever, came into actual contact. The palmar facet for the lunar is of large size and occupies the entire lunar face of the palmar process of the scaphoid. Between the different facets the lunar face of the scaphoid is much excavated and extensively arched in the antero-posterior direction. The latter character is chiefly due to the excessive outward turn of the large palmar process. Distally the scaphoid has three facets: one posterior for the trapezoid, one anterior for the magnum, while on the ulnar angle there is a long narrow facet which also articulates with the high and antero-posteriorly directed ridge on the proximal face of the magnum. The articular surface for the trapezoid is concave antero-posteriorly and is continuous with the surfaces for the magnum. The two latter surfaces are irregularly convex and concave. Radially the bone is quite rugose and gently convex, while the anterior face is much more convex from side to side.

From Kowalevsky's illustration (**38,** Pl. XXVI, fig. 23) it would seem that the scaphoid of *Entelodon* has a smaller antero-posterior diameter, when compared with its vertical dimension, than is seen in the American forms. In *Anthracotherium* (see Kowalevsky, Paleontographica, Vol. XXII, p. 299; Pl. XI, fig. 38) the scaphoid has a remarkably close similarity to the scaphoid in the *Entelodontidæ*, as has been pointed out by Kowalevsky and Scott (**87,** p. 303). The scaphoid in *Sus* and *Hippopotamus* on the other hand is more unlike that in the *Entelodontidæ*, being broader, and of smaller antero-posterior diameter.

Lunar.—The lunar of *Dinohyus* is distinctly more modified than is the case in *Entelodon* and *Archæotherium*. In *Dinohyus* the vertical and antero-posterior diameters in relation to the transverse, are greater than in the Princeton specimen, a character naturally to be looked for in a later form. As in *Archæotherium*, the facet for the radius is divided into two parts, an anterior and a posterior; the former has a less abruptly rounded transverse ridge than in *Archæotherium*, and the latter has a relatively greater antero-posterior diameter and is deflected on the ulnar side to a greater degree. The dorsal face has a slightly different outline from that figured by Kowalevsky (**38,** Pl. XXVI, figs. 21–32), and also different from that which appears in the Princeton specimen. The principal difference in outline from that of the older forms is caused by the convex facet for the magnum on the radial face. In *Archæotherium* the facet is altogether the reverse, being concave instead of convex (see fig. 71). In *Dinohyus* it is seen that both the magnum and the unciform have yielded to the development and modification of the beak of the lunar so that the lateral contact of the two is entirely lost dorsally, and the lower end of the lunar is almost in touch with the proximal end of the third metacarpal (see fig. 70, 2). The beak which is more bluntly pointed than in *Archæotherium* is also apparently shifted farther toward the radial side than in the latter genus. The palmar face has a more oblique outline above; otherwise it is quite similar to that of the Oligocene genus. The ulnar side has two facets for the cuneiform, which are almost identical with those of *Archæotherium*. The dorso-proximal facet for the scaphoid is more clearly defined than in *Archæotherium* and the changed condition of the dorsal facet for the magnum, as stated above, gives to the radial face of the bone a more nearly vertical position than in the latter genus. The posterior portion of the facet for the magnum is recurved downward and developed into a hook on the posterior radial angle, which is relatively larger than in the Princeton specimen.

FIG. 71. Anterior View of Portion of Fore Foot of *Archæotherium crassum* Marsh. ½ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 1665.)

MEASUREMENTS.

					Mm.
Lunar, greatest	antero-posterior	diameter			60
"	"	transverse	"	anteriorly	45
"	"	"	"	posteriorly	50
"	"	vertical	"	anteriorly	60
"	"	"	"	posteriorly	45

Pyramidal. — In *Dinohyus* the posterior ascending tubercle of the facet for the ulna is more prominent than in *Archæotherium,* which results in a greater concavity antero-posteriorly in the former. The facet for the ulna extends down on the bone in an unusual manner and hence it is proportionally greater than in *Archæotherium, Hippopotamus,* or *Sus.* The pisiform facet is more oblique than in the Oligocene form. Below this facet is a large and deeply excavated sulcus which extends parallel to the sharp ridge on which is located the above mentioned facet. The radial face has two facets for the lunar; the supero-anterior one is plane, subtriangular in outline, and inclined obliquely upward and outward; the postero-inferior facet is convex antero-posteriorly and concave supero-inferiorly and separated from the ulnar facet by a sharp ridge, while in *Archæotherium* the two facets are separated by a sulcus of considerable diameter. The distal articular facet is similar to that of the Princeton specimen in every respect.

MEASUREMENTS.

					Mm.
Pyramidal, greatest	antero-posterior	diameter			61
"	"	transverse	"	posteriorly	43
"	"	vertical	"	anteriorly	43
"	"	"	"	posteriorly	64

Pisiform. — There is no pisiform present with the type of *Dinohyus.* In another specimen (No. 2136, Carn. Mus. Cat. Vert. Foss.) the pisiform was found nearly in position and is here described in connection with the type specimen. There are only slight differences in the shape of the pisiform of *Dinohyus* and that of the older American types. The facet for the ulna extends slightly further back and is surrounded by a much heavier border so that the proximal face of the shaft has a deep excavation while in *Archæotherium* it is more evenly rounded. The facet for the pyramidal is larger than that for the ulna. From the attachment of the carpus the bone is strongly recurved backward and radially as in *Archæotherium* and the free end is enlarged into a thick knob. The bone, though comparatively small, is relatively of slightly larger size than that of the Oligocene genus.

The pisiform of *Entelodon,* as Scott (**87,** p. 304) has pointed out, is very different in its outline, though not altogether unlike that of the American forms. Scott suggests that the irregular shape of the pisiform which Kowalevsky (**38,** Pl. XXVI, fig. 27) figures "might be due to disease." It would, however, seem from the illustration that the facets also differ in having an irregular convexity while in the American forms they are obliquely concave. The pisiform of *Anthracotherium* is considerably larger and somewhat different in form, having a more decided shaft, a less club-shaped free end, and apparently differently shaped articular facets for the

carpus and ulna (Palaeontographica, Vol. XXII, Pl. XI, fig. 58). In *Sus* the pisiform is shorter, thinner, and deeper, while in *Hippopotamus* it has a general similarity to the pisiform of the *Entelodontidæ*.

MEASUREMENTS.

	Mm.
Pisiform, greatest length	70
" vertical diameter of proximal end	32
" transverse " " " "	31
" " " " distal "	32
" vertical " " " "	30

Trapezium. — The trapezium of *Dinohyus* is no doubt entirely wanting, judging from its rudimentary condition in the Oligocene genus,[48] and its entire absence in the John Day form. Professor Cope states (**10,** pp. 62–63) that there is no trace of a facet for a trapezium on the trapezoid of *Boöchœrus humerosus*, which was verified by me on examination of the type specimen in the American Museum.[49]

Trapezoid. — Though absent in the type of *Dinohyus* this bone was found in position on the magnum of a fore foot, found in section 19 (see plan of quarry, Pl. LIV, No. 47) and is here described.

The transverse diameter of the trapezoid (No. 2136, Carn. Mus. Cat. Vert. Foss.) is only two millimeters greater than in *Archæotherium*, while the antero-posterior diameter is proportionately somewhat greater. The bone is consequently much compressed laterally and has a subquadrate outline, when viewed from its ulnar face. Radially the proximal face is more rounded before backward, by the articulating surface for the scaphoid, which gives this (radial) face a more irregular quadrate appearance. The transverse diameter of the bone is greatest proximally, and it gradually tapers distally, terminating in a border, which is rather narrow and rounded inferiorly. The facet for the scaphoid is obliquely convex antero-posteriorly and extends well back on the posterior face of the bone. The ulnar face bears three facets for the magnum, two of which are distal and one proximal. The proximal facet is well defined near the dorsal face and continues backward as a smooth rounded ridge on the proximo-ulnar angle. The two distal facets are a palmar and a dorsal, and may be regarded as practically one facet, as they are divided only by a very shallow, almost imperceptible, groove, while in *Archæotherium* there is a moderately large median swelling on the ulnar face which puts the two facets at a considerable angle with each other.

[48] There is, in the Princeton specimen described by Professor Scott, a trapezium with a well formed facet for the trapezoid, and the bone, though laterally compressed, is of considerable size antero-posteriorly and extends well down over Mc. II, but does not articulate with the latter. (See fig. 10 on page 55.)

[49] In my note book I find the following statement regarding the trapezium of *Boöchœrus*: "The trapezoid has a small pit radially which may have lodged a trapezium, but there is no distinct facet."

Between the proximal and distal facets the surface of the bone is very slightly excavated while the corresponding face on the magnum is very deeply excavated, forming a large sinus. Radially there is but one small facet: that for the rudimentary Mc. II (see fig. 72). This facet is situated near the dorsal face and has a radial position, while that in *Archæotherium* described by Professor Scott (**87,** p. 305) is directly on the distal face. There is no facet for the trapezium, while in *Archæotherium* the facet is quite plain and the trapezium is present.

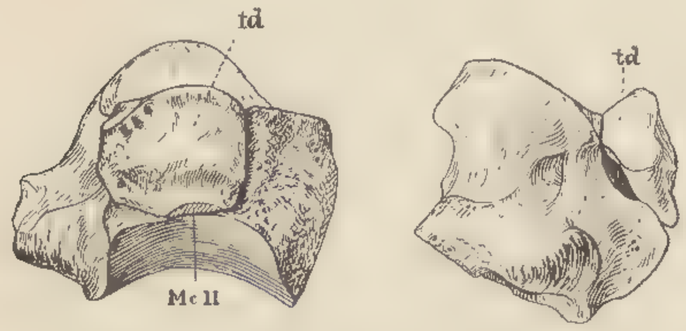


FIG. 72. Radial and Palmar Views of Magnum with Trapezoid in Position. ½ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2136.)

In the European genus *Entelodon* the trapezoid is not known, which is also true of *Anthracotherium.*

The trapezoid in *Sus* and also in *Hippopotamus* is relatively large; it has more functional importance in the make-up of the carpus, and can hardly be compared with the rudimentary form, which the bone possesses in the *Entelodontidæ.*

MEASUREMENTS.

	Mm.
Trapezoid, antero-posterior diameter	28
" transverse "	12
" vertical "	25

Magnum. — Proximally there are two oblique facets on the magnum: an antero-radial for the scaphoid; and a postero-ulnar for the lunar. The former facet is concave from side to side and convexo-concave from before backward. The latter facet is convex antero-posteriorly and concave on the postero-ulnar angle presenting a sinuous surface, which terminates behind in a beak-like process on the proximo-ulnar angle of the palmar process. In *Archæotherium* the palmar process is placed more distally and has not an upward recurved beak, as in the present genus. The facet for the scaphoid is relatively broader and more concave on the ulnar angle than in the Princeton specimen. The facet for the lunar has a proportionally smaller transverse diameter than in *Archæotherium* and the dorsal contact with the lunar is entirely lateral and concave supero-inferiorly, while in *Archæotherium* it is convex in order to receive the concave facet of the lunar, as stated above. The ulnar side has two deeply excavated areas; one of large size in front, and one smaller, back of a broad obliquely located ridge, which terminates above in the lateral facet for the unciform. This ridge is much less developed in *Archæotherium.* The groove for the trapezoid seen in the latter genus is less clearly defined in its vertical portion in *Dinohyus,* while in the antero-posterior direction it is

broadly developed. This is due to the fact that the extension of the superior border articulates with the scaphoid, while the inferior border articulates with Mc. III in *Dinohyus*. The articulation for the trapezoid is also relatively smaller and reduced to two facets, a small superior and a larger inferior, while in *Archæotherium* there are three facets, one superior and two inferior. The palmar process is compressed laterally, but attains a considerable vertical diameter, reaching the lunar above and articulating with it by a beak-like process referred to above. The position of the palmar process is oblique and the shape is thus very different from what appears in the Princeton specimen, described by Professor Scott (**87,** p. 306), which has a more rounded palmar process. The head of the magnum rises more abruptly toward the palmar side in *Dinohyus* than in the Oligocene genus, which Scott used for his comparison with the European form. In the latter Scott says "the head of the magnum rises less abruptly toward the palmar side." In *Hippopotamus* the palmar hook is even more prominent, but is placed more transversely and is extended more downward than in *Dinohyus*. Distally there is in the latter genus only one articulation, that for the third metacarpal. It is concave antero-posteriorly and convex laterally. The antero-posterior diameter of the facet is proportionally greater than in *Archæotherium ingens*.

The magnum of *Entelodon* figured by Kowalevsky (**38,** Pl. XXVI, figs. 21, 23, 29–32) is, as Scott has stated (**87,** 306), generally similar to that in the American genera, but there are a number of minor differences. The facet for the scaphoid in the European genus is less horizontal; the facet for the lunar is more oval in form and is not continued outward on the palmar hook; the articulation for the trapezoid is relatively larger and is in a different position, *i. e.*, near the dorsal face and also at the palmo-distal angle of the bone. The palmar process is relatively as large as in *Dinohyus*, but different in shape, being more rounded. The sulcus, which on the distal ulnar face separates the lunar facet, is very much smaller than in *Dinohyus*.

MEASUREMENTS.

					Mm.
Magnum, greatest	antero-posterior	diameter			70
"	"	transverse	"	posteriorly	47
"	"	"	"	anteriorly	43
"	"	vertical	"		58
"	"	"	"	anteriorly	31

Unciform. — The greatest antero-posterior and transverse diameters of the unciform are very nearly equal. The bone as a whole is massive, and is, as in *Boöchœrus humerosus*, the second largest bone of the carpus. Its anterior face is rugose and unevenly convex transversely. Posteriorly there is a palmar hook not unlike that

of *Hippopotamus*, though somewhat less produced downwards. At the base of this palmar process on the ulnar side there is a facet for Mc. V, which meets the facet for the pyramidal at right angles. In *Archæotherium ingens* these two facets are separated by a considerable surface, which is concave vertically and convex transversely. The radial side is occupied by a large facet for Mc. III, which is strongly inclined radially. Back of this facet is a large excavated area, which extends over the remainder of the radial face of the bone. The small oblique facet for the magnum on the radial angle of the unciform in *Archæotherium* is almost entirely proximal in *Dinohyus*, and passes imperceptibly into the lunar facet. Proximally the lunar and pyramidal articulations are divided by a prominent ridge, which extends anteroposteriorly, the pyramidal facet being the larger of the two. The distal face is occupied almost entirely by the large facet for the fourth metacarpal, which on the radial angle presents an abrupt continuation of the facet for Mc. III as in *Archæotherium*. There is no dorsal articular surface for the magnum on the radial face, as in older forms[50] of this family, and these two bones (unciform and magnum) when in position in the carpus appear well separated (see fig. 70).

Professor Scott has already pointed out that "the unciform of Kowalevsky's specimen does not differ in any significant way from that of the American species" (**87,** p. 306). In *Hippopotamus* and *Sus* the unciform is larger, which is due to the tetradactylous condition of the feet in these genera.

MEASUREMENTS.

	Mm.
Unciform, greatest antero-posterior diameter	64
" " transverse "	54
" " vertical "	47

Metacarpal II. — The second metacarpal is not present in the type of *Dinohyus*, but a deep vertical groove on the lateral face and a minute articular facet on the proximal angle of the third metacarpal indicate the presence of this bone. In my notes on *Boöchœrus humerosus* in the American Museum, I find it stated that Metacarpal II has two facets proximally: one small one for the trapezoid and a larger one for the facet on the radial face of Mc. III. The reduction of these two elements (trapezoid and Mc. II) in the manus of the Nebraskan Miocene form is in all probability carried to a greater degree than in the John Day form. The second metacarpals of the fore feet are present in the Princeton specimen, which Professor

[50] In the type of *Boöchœrus humerosus* the unciform and magnum are separated, but not to the same extent as in *Dinohyus;* the beak of the lunar in the latter genus extends lower down than in the former. This fact is not well illustrated in fig. 15 on page 61 where the lunar appears too low.

Scott described (*l. c.*, p. 307). They are small nodular bones with well defined facets for Mc. III, the magnum, and the trapezoid, but with no facet for the trapezium.

Metacarpal III. — Unfortunately the third metacarpal is represented only by the proximal and distal ends, as the contact of the shaft was lost in collecting the material. The head is much expanded transversely, especially on the ulnar side, which has a heavy cubital process articulating with Mc. IV and the unciform in an interlocking manner. Besides the dorsal articulation for Mc. IV, there is also a palmar articulation on the ulnar side, which is located on the very prominent palmar process. Continuous with the latter facet, and separated from it only by a sharply defined ridge, is a facet evidently for a palmar sesamoid.[51] Proximally the bone is taken up by the large facet for the magnum, which is convex antero-posteriorly and concave laterally. On the dorso-ulnar angle is a smaller and obliquely placed facet for the unciform referred to above. The radial side is excavated quite deeply and has two facets, one dorsal and one palmar, for the rudimentary Mc. II; the dorsal facet is quite large and is wedge-shaped in outline with the apex downward; the palmar facet consists only of a minute rounded ridge on the radial angle of the articular surface of the magnum. The shaft of the bone is quite broad transversely and compressed antero-posteriorly. When held in a vertical position the distal trochlea is well shown on the anterior face of the bone, less so behind. The metapodial keel is confined only to the plantar portion and is proportionately less developed than in the Oligocene genus. In general appearance there are no very marked differences of the metacarpals from those of the known earlier forms; though in the present genus they are relatively of slightly greater length, and have rugosities on the inner sides. The comparative length of the metapodials with the upper arm-bones is a significant feature in *Dinohyus*.

Professor Scott states that the third metacarpal in Kowalevsky's specimen (**87,** p. 307) "does not differ in any important way from that of the American species, though the magnum facet is somewhat more concave transversely and the shaft is rather more slender." Kowalevsky, however, points out (**38,** p. 444, Pl. XXVI, fig. 23) that there are three facets on the radial face of Mc. III, of which the two lower undoubtedly articulated with the rudimentary Mc. II, while the upper one articulated with the trapezoid. In all the specimens of the American forms, which I have examined and in which these parts were present, I have not been able to find more than two facets, those for Mc. II, on the radial face of Mc. III. From this fact it is quite evident that the trapezoid in *Entelodon* had not suffered the reduction, which is seen

[51] In specimen No. 2136 (Carn. Mus. Cat. Vert. Foss.) this palmar process was found very nearly in position (see fig. 70, ps.).

in the American forms, and had a somewhat similar though less prominent contact with Mc. III, as in *Sus*. In *Anthracotherium*, the general similarity of Mc. III (Palæontographica, Vol. XXII, p. 308, Pl. XIII, fig. 80) to that of the *Entelodontidæ* is quite striking, as Scott has pointed out, but it "is relatively heavier; at the proximal end the tubercle for the insertion of the extensor carpi radialis muscle is more conspicuous, and the palmar projection of the head more prominent." To this might also be added that the facet for the trapezoid is apparently indicated, which is naturally to be expected in a tetradactyl form, although Kowalevsky does not mention it.

MEASUREMENTS.

	Type No. 1594. Mm.	No. 2136. Mm.
Metacarpal III, greatest length		240
" " antero-posterior diameter, proximal end	57	58
" " transverse " " "	57	65
" " antero-posterior " distal end	45	46
" " transverse " " "	54	55

Metacarpal IV. — The fourth metacarpal is complete in the type, and, as in the earlier forms of this family, smaller than the third. There are two articulating surfaces on the proximal face, one for the unciform and the other for Mc. III. The former is large and nearly triangular in outline; the latter has a wedge-shaped outline with the apex directed posteriorly. On the radial side are two facets, one dorsal and the other palmar; the two articulate with Mc. III. On the radio-palmar angle is a third facet of small size, which supports a palmar sesamoid (see fig. 70). On the ulnar side there is a prominent process, which has a round articular surface for Mc. V. The shaft has the greatest constriction immediately below the head and gradually becomes wider distally. There is no essential difference in the distal trochlea from that of Mc. III.

MEASUREMENTS.

	Type No. 1594. Mm.	No. 2136. Mm.
Metacarpal IV, greatest length	215	220
" " antero-posterior diameter, proximal end	58	56
" " transverse " " "	62	63
" " antero-posterior diameter, distal end	44	45
" " transverse " " "	55	57

Metacarpal V. — The fifth metacarpal is a rudimentary almond-shaped sesamoid which is of about the same proportionate size as that in *Archæotherium*.[52] Proximally there are two distinct articular surfaces: a superior one for the unciform, and an inferior one for Mc. IV.

[52] The fifth metacarpal in *Boöchœrus humerosus* from the John Day formation is apparently of greater size and also longer than in *Dinohyus*.

MEASUREMENTS.

	Mm.
Metacarpal V, greatest length	40
" " transverse diameter	25

Phalanges. — The proximal and second phalanges are broad and depressed. The proximal phalanx has a shallow groove for the metapodial keel, confined to the plantar portion of the proximal articulation. Distally there is a smooth articular surface for the second phalanx, which is convex antero-posteriorly and concave transversely. The articulation is carried around upon the plantar surface of the bone, but does not extend very high up on the dorsal face. The plantar face has prominent rugosities for attachments not unlike what is seen in the recent camels. The second phalanx is even more suggestive of the camel though relatively much shorter and less depressed. It is unusually broad on the plantar face, but slopes rapidly dorsally. The proximal end has a smooth surface, which is deeply concave supero-inferiorly and gently convex laterally, to receive the correspondingly smooth surface of the distal end of the proximal phalanx. The distal trochlea is flexed in a much greater degree, especially dorsally, than that of the proximal phalanx. The bone is quite asymmetrical, having the internal border shorter than the external and also very rugose and heavy, while the external border shows no unusual characters.

The ungual phalanges of the fore foot are not present in the type, but fortunately they are represented in the fore foot of specimen No. 2136 (Carn. Mus. Cat. Vert. Foss.). This bone is unusually short and quite high. Anteriorly the ungual phalanx is much truncated and the bone as a whole has a curious nodular shape. The plantar surface is quite broad and convex in all directions except posteriorly. The sides slope rapidly to form a rounded and prominent dorsal ridge; this ridge terminates on the postero-dorsal angle in a broad, rather large and truncated tubercle for ligamentary attachments. Proximally there are two articulating facets for the phalanx of the second row, an external and an internal, and these are imperfectly divided by an oblique ridge.

The phalanges of *Entelodon*, which Kowalevsky figures (**38,** Pl. XXVII, fig. 38), are quite similar in shape to those in the American forms, except that the proximal phalanx according to this author is relatively longer in *Entelodon*. By comparative measurements it seems that the three[53] phalanges of a digit in *Enteledon* are together perhaps longer than those in the American genera of this family; in *Sus* the phalanges are of a different shape, the proximal being thicker in proportion to its length, with a deeply grooved proximal trochlea for the keel of the distal end of the metapodial, while the ungual is longer, broader, and more pointed. In the Ameri-

[53] The ungual phalanx of *Entelodon* is not known and is here only estimated.

can forms of the *Entelodontidæ* on the other hand the three phalanges together are far from being as long as the metapodial. In *Hippopotamus* the ungual is reduced and has a nodular form, as in the Entelodonts, while the proximal and median phalanges are broad and very heavy.

MEASUREMENTS.

	Mm.
Greatest length of a first phalanx	78
" transverse diameter of a first phalanx, proximally	54
" antero-posterior diameter of a first phalanx, proximally	44
" transverse " " " " distally	48
" antero-posterior " " " " "	38
" length of a second phalanx	58
" transverse diameter of a second phalanx, posteriorly	41
" antero-posterior diameter of a second phalanx, posteriorly	35
" " " " " " distally	38
" transverse " " " " "	43

THE HIND LIMB.

Pelvis. — The only part of the pelvis of the type which is preserved is the posterior portion of the pubic symphysis. This fragment agrees, except in its larger size, with the corresponding portion of *Archæotherium ingens* from the Oligocene.

FIG. 73. Superior View of Pelvis of *D. hollandi* Peterson. $\frac{1}{6}$ nat. size. (Carn. Mus. Cat. Vert. Foss., No. 2126.)

In one individual of *Dinohyus* (No. 2126, Carn. Mus. Cat. Vert. Foss.), secured in 1908 in Quarry No. 1, Sec. 17 (see plan of quarry, Pl. LIV) there is found a nearly complete half of a pelvis, not fully adolescent, but which apparently agrees quite well in size with the type. A second specimen (No. 2139, Carn. Mus. Cat. Vert. Foss.) of smaller size found in section 19 (No. 33) has the pelvis practically complete. The former specimen will be used in this description as a paratype, while the latter, which may represent another species, is used only to more fully elucidate the description.

It is at once observed that the pelvis of *Dinohyus* is relatively shorter though

slightly deeper than that of *Archæotherium ingens* from the lower Oligocene formation. The shortening of the pelvis is principally confined to the region back of the acetabulum. The ilium has nearly the same relative length as in the Oligocene genus, and its anterior plate is suddenly expanded into a strongly everted antero-inferior portion. The dorsal surface of the ilium is basin-like, the entire crest having a slightly everted border. Ventrally it is strongly convex and the greater portion of its surface is taken up with the attachment for the sacrum. The latter is so placed that when articulated with the vertebral column the pelvis has a more vertical position than in *Archæotherium*. The shaft of the ilium is relatively shorter than in *Archæotherium*, but has the same general trihedral out-

FIG. 74. (1) Lateral View of Pelvis of *Archæotherium ingens* Leidy (Princeton Museum, No. 10885). (2) Lateral View of Pelvis of *Dinohyus hollandi* Peterson (Carn. Mus. Cat. Vert. Foss., No. 2126). $\frac{2}{5}$ nat. size.

lines, while its ilio-pectineal tubercle on the inferior border is heavier than in the latter genus. The great sacro-sciatic notch has a heavy rounded border on its anterior margin, while further back the border becomes sharper, though not to the same degree as in *Archæotherium*. The ventral or anterior border of the ilium has a sharper border than the notch above and is arched to a greater degree than in *Archæotherium*, which is chiefly due to the larger development of the ilio-pectineal eminence in the Miocene genus. In *Hippopotamus* the ilium is not very like that

of the *Entelodontidæ*, the peduncle being shorter and much heavier, the ilio-pectineal eminence wanting (except a slight enlargement at the extreme anterior border of the acetabulum), and the anterior portion flares out into a heavy fan-shaped plate with little or no eversion such as is found in *Archæotherium* and *Dinohyus*.

The ischium, as has already been said, is much shorter in *Dinohyus*, and its vertical diameter posteriorly is somewhat greater than in the Princeton specimen. The depressed area for ligamentary attachments takes up a considerable space of the acetabulum and the cotyloid notch is wide, though quite shallow. The dorsal border, or spine, of the ischium is not nearly so prominent as in *Archæotherium*, and the lesser sacro-sciatic notch is quite short, with a heavy rounded border, which gradually decreases in its backward trend. Posteriorly this notch is suddenly recurved, due to the anterior extension of the prominent tuberosity of the ischium.

The vertical diameter of the ischium from the point of the tuberosity to the symphysial border, is relatively somewhat greater in *Dinohyus* than in *Archæotherium*, and this results in giving the former genus a slightly deeper pelvic cavity. In *Hippopotamus* the body of the ischium back of the acetabulum is longer and more nearly circular in outline than is known in the Entelodonts, and posteriorly it flares out to form a heavy tuberosity as in the latter family, but the symphysis of the ischium is rather delicately developed. Another important difference is seen in the small area of the acetabulum taken up by the ligamentary attachments and the small deep cotyloid notch in *Hippopotamus*.

The pubis, though short, is relatively slightly longer than in *Archæotherium*. In the region of the spine the pubis is very heavy and there is a large symphysial surface which meets that of its fellow, making the symphysis unusually heavy. Further back the ramus of the pubis is thinner and unites with the ischium to form the lower border of the obturator foramen. The latter is of large size, but is, as might be expected, less elongated in the antero-posterior direction than in *Archæotherium*. In neither *Sus* nor *Hippopotamus* is there any marked similarity to the Entelodonts in the region of the pelvis, though there is more general resemblance, as Professor Scott has stated (**87**, p. 310), between the latter genus and the Entelodonts than there is in the former.

MEASUREMENTS OF PELVIS.

	Mm.
Greatest length, approximately	490
Length from middle of acetabulum to end of ischium	195
" " " " " " crest of ilium, approximately	300
Greatest vertical diameter of ischium	192

Femur. — The femur is complete, except the great trochanter which was lost in the process of collecting. The femur is long and slender, but proportionately

heavier, and also considerably shorter, than in the Princeton specimen. The head is well rounded; it is set on a distinct neck, and the depression for the ligamentum teres is rather small and shallow. The lesser trochanter is quite large, and projects, as in the Oligocene genus, almost entirely backward.[54] Between the greater and lesser trochanters is a ridge extending obliquely across the posterior face of the shaft which is more prominent in the present genus than in *Archæotherium*. Immediately in front and superior to the lesser trochanter is a prominent and very rugose ridge, which runs parallel with the shaft and is separated from it by a deep groove. The middle region of the shaft is proportionally less constricted than in *Archæotherium* and the linea aspera is more developed than in the latter genus, a character which agrees better with what we know of *Boöchœrus* through Cope (**10,** p. 65). The large and rugose groove above the external condyle, for the plantaris muscle, terminates above in a heavy and very rugose tubercle; immediately above the internal condyle on the posterior angle there is a prominent ridge for muscular attachment. The shaft of the femur as a whole is more arched than in the Princeton specimen. The rotular trochlea is short, not very deep, but broad, and slightly oblique. The condyles are rather small, the external being the larger of the two, and placed more directly fore-and-aft than the internal. The intercondylar fossa is deep, oblique, and wider in front than behind.

FIG. 75. Internal and Anterior Views of Femur of Type of *D. hollandi* Peterson. ¼ nat. size.

One of the more important differences between *Dinohyus* and *Boöchœrus humerosus* is revealed in the comparative diameter of the distal end of the femur. In *Dinohyus* the femur has the antero-posterior diameter proportionately greater than in *Archæotherium ingens*, and in this respect *Dinohyus* more nearly resembles *Hippopotamus*, while, in *Boöchœrus humerosus* the diameter of the distal end is more nearly

[54] Cope states (Bull. U. S. Geol. Surv., Vol. V, p. 65, 1880) that the lesser "trochanter is large and projects well inwards."

equal transversely and antero-posteriorly, like what may be observed in *Sus* and the peccaries. Unfortunately no complete femur of *Boöchœrus humerosus* has been as yet discovered and we are therefore unable to compare it with the corresponding bone of earlier and later forms.

MEASUREMENTS OF FEMUR.

	Mm.
Greatest length	470
" transverse diameter of proximal end, approximately	155
Antero-posterior diameter of head	63
Transverse " " "	63
Greatest antero-posterior diameter of distal end, approximately	144
" transverse " " " "	120
Diameter of shaft at middle..... transverse	53
Diameter of shaft at middle..... antero-posterior	56

Patella. — The patella which was found with the type and undoubtedly belongs to the same individual, is quite different from those found with the Princeton specimen. The diameters are relatively smaller in the vertical and antero-posterior directions, while transversely they are greater than in *Archæotherium.* The general outline of the bone is sub-oval, with a short, blunt process below and an angle greater internally than externally. It is evenly convex in front. The articular facet for the rotular trochlea of the femur is evenly rounded without a separating ridge, which agrees perfectly with the condition of the groove of the femur. The patella of *Dinohyus* is further characterized by having a considerable rugose area on the postero-internal angle which is separated from the main articulation by a very narrow,

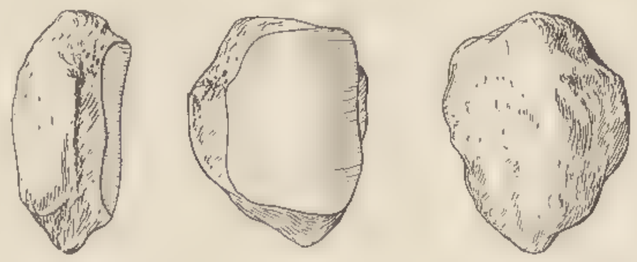


FIG. 76. Lateral, Posterior, and Anterior Views of Patella of Type of *D. hollandi* Peterson. ¼ nat. size.

but well marked groove. In *Archæotherium* instead of this rugose area there is a small recurved tubercle, which adds to the transverse diameter of the femoral articulation of the patella. The patella of *Boöchœrus humerosus* is relatively larger than that of *Dinohyus hollandi* and in this respect more nearly resembles that of *Archæotherium ingens;* the general shape is also more nearly like that in the latter genus, though there are some differences, for instance in *Boöchœrus* the patella is more massive, with a rapid contraction in the lower portion to form a process distally, while in *A. ingens* the patella is of the greatest antero-posterior diameter proximally and gradually diminishes to a transversely broad and antero-posteriorly compressed process.

MEASUREMENTS OF THE PATELLA.

	Mm.
Vertical diameter....	100
Tranverse "	68
Antero-posterior diameter....	40

Tibia. — One of the more noteworthy characters of *Dinohyus* is seen in the coössification of the tibia and fibula. In the Princeton specimen from the Oligocene the fibula, though much reduced, is entirely free, while in *Dinohyus* it is firmly coössified. The internal condyle extends somewhat more over the shaft than in *Archæotherium*, which results in a relatively greater expansion. The two condyles are separated by a prominent spine which rises more abruptly than in the older forms. The cnemial keel is prominent and extends very nearly to the middle of the shaft before it disappears. On the internal face of the cnemial crest the shaft is quite flat, while externally there is a large fossa for the flexor tendon, which is bounded superiorly by the expanded head and the deep tendinal groove, laterally by the high cnemial keel and the rounded external border; distally the fossa gradually becomes shallower and finally fades away on the shaft below the cnemial keel. Posteriorly there is another prominent fossa for the tibialis posticus, which is bounded above by the overhanging borders of the popliteal notch, and laterally by the internal and external borders of the bone. Distally the fossa fades away and the surface of the shaft is almost flat, while internally, externally, and anteriorly, there are greater convexities imparting to the bone a sub-oval cross-section. More distally the shaft becomes nearly quadrate.

FIG. 77. Anterior View of Tibia-fibula of Type of *D. hollandi* Peterson. ¼ nat. size.

The transverse expansion of the distal end is not great and the antero-posterior diameter is only very moderate. The trochlea is unequally divided by a prominent ridge extending antero-posteriorly; the external portion is the larger, and more elevated than the internal, which causes a considerable obliquity of the trochlea. This character is more nearly like what may be observed in the *Merycoidodonts* (*Oreodonts*) than any of the recent *Suidæ*. The bifid termination at the anterior margin of the intercondylar ridge in *Archæotherium* is absent in *Dinohyus*, and instead there are two facets on the extreme antero-inferior end, which touch corresponding facets in the median portion of the neck of the astragalus when the tibia is flexed forward. A similar arrange-

ment is also seen on the intercondylar ridge of the tibia in *Dæodon calkinsi* from the John Day formation. The articulating surface of the inter-condylar ridge is proportionately more interrupted than in the Oligocene genus, as the irregular-shaped sulcus continues to the posterior border, at which point it entirely separates the articulations of the trochlea. The internal malleolus is rather small; it is compressed transversely, does not extend much below the distal end of the fibula, and it covers only one-half of the antero-posterior diameter of the trochlea.

The proximal end of the fibula is well coössified with the head of the tibia. Immediately below the head the shaft is separated from the tibia for a distance of 100 mm.; below this point the fibula, as stated above, is entirely fused with the tibia leaving little or no trace of a suture between the two bones, except at the distal end. The distal end is much expanded antero-posteriorly and rather compressed transversely. On the anterior half of the external face is a prominent vertical ridge which forms the anterior border of the tendinal groove and extends upward for a distance of 60 mm. where the ridge becomes rapidly contracted and disappears on the side of the fibular face. Distally the fibula extends well down below the trochlea and furnishes a symmetrical appearance to the outline of the distal end of the tibia-fibula.

Kowalevsky in his memoir figures a tibia and a portion of a fibula which was found with *Entelodon magnum* (**37,** Pl. XXVII, fig. 33).

These illustrations, together with the casts of the specimens now in the Carnegie Museum, present characters quite similar to those of the corresponding bones in the older American forms. The proximal end of the tibia of *Entelodon* is possibly somewhat more expanded, but this may be due in great measure to crushing, as the bone has apparently received some injury laterally. The fibula, which is quite delicate, is represented by a portion of the shaft lying closely appressed to the shaft of the tibia as figured by Kowalevsky. This bone appears to have been turned end about; the lower portion, as seen in the specimen, apparently agrees better with the proximal than distal end of the American forms.

MEASUREMENTS OF TIBIA.

	Mm.
Greatest length	450
" antero-posterior diameter of proximal end, approximately	115
" transverse " " " "	126
" " " " distal "	97
" antero-posterior " " " "	65

The Hind Foot.

As in other representatives of the *Entelodontidæ*, the pes, as well as the manus of *Dinohyus*, is didactyl. The total absence of the facet on the cuboid [55] for mt. V in the type of *Dinohyus hollandi* is interesting and of some importance in connection with other modifications of the genus. Professor Scott states (**87,** p. 318) that in *Archæotherium ingens* from the Oligocene of America the fifth metatarsal is present. From Kowalevsky's statement and figures it is also very evident that *Entelodon magnum* of Europe had a fifth metatarsal (**38,** p. 449, Pl. XXVII, fig. 35). Unfortunately the cuboid and mt. IV of the type of *Boöchœrus humerosus* from the John Day formation, are badly preserved in the region where the facet for mt. V would be found, so that its presence or absence is only a matter of speculation. Through the courtesy of Professors Schuchert and Lull the writer had the opportunity of studying the material representing Entelodonts which was collected for Professor Marsh from the John Day region as long ago as 1875. In this collection is a portion of a skeleton of an Entelodont from the green sandstone (probably the middle beds) which is somewhat smaller than *Boöchœrus* described by Cope. The general features of the remains seem to indicate a more primitive type having a closer resemblance to *Archæotherium ingens* from the Oligocene than the new genus *Dinohyus*. On the cuboid of this specimen from the John Day formation the facet for mt. V is plainly indicated.

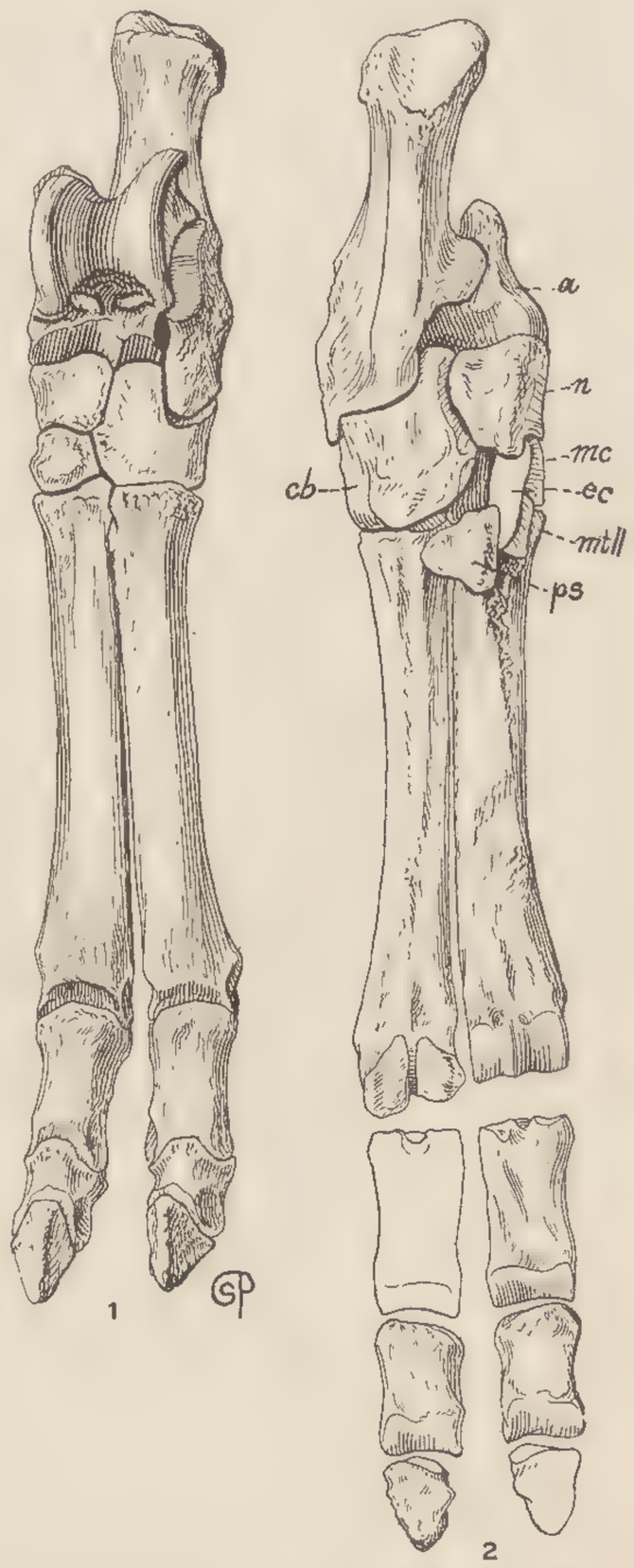


FIG. 78. Dorsal and Palmar Views of Left Pes of Type of *D. hollandi* Peterson. *ps*, palmar sesamoid. ½ nat. size.

Astragalus. — In correspondence with the oblique trochlea of the tibia the proximal

[55] A cuboid (No. 1926) referred to this genus, which was found in quarry No. 2 (Agate Spring Fossil Quarries), is somewhat heavier than that in the type. The two specimens, which represent two individuals, are almost identical in their general characters, except that in No. 1926 there is present a minute articular surface for mt. V, which would seem to indicate individual or specific differences.

trochlea of the astragalus displays considerable asymmetry. The external condyle is much higher and more produced dorsally than the internal condyle, but the articular surface does not extend so far distally on the anterior face as that on the internal condyle, which nearly meets the articulation for the navicular. The pit on the dorsal face, which separates the distal and proximal articulations, is large, comparatively shallow, and in the bottom are located two facets, which articulate with corresponding facets on the anterior termination of the intertrochlear ridge of the tibia when the latter is flexed forward. In *Archæotherium* this pit is deeper and has no facets. The trochlear articulation of the external and internal condyles of *Dinohyus* are entirely separated by a broad sulcus, which takes up the deepest part of the trochlea and is directly opposite the corresponding sulcus on the intertrochlear ridge of the tibia when the two bones are in position. The distal trochlea is oblique and unequally divided into two facets, the navicular facet being larger than the cuboidal. The latter facet is proportionally of a less transverse diameter than that in the Princeton specimen, which indicates a tendency toward the narrowing up of the tarsus. The distal trochlea as a whole is more deeply concave on the median line, the ridge separating the two facets being more prominent than in the Oligocene genus. The sustentacular facet is relatively limited in the vertical direction and also somewhat narrower superiorly when compared with that in *Archæotherium*. There are three calcaneal facets externally; one is situated on the extreme distal angle of the bone, while the other two are superior to the deep cavity which takes up a large area of the external face.

The appearance of the astragalus figured by Kowalevsky (**38,** Pl. XXVII, fig. 34) is not unlike that of the American genera, although the pit on the dorsal face, which separates the proximal and distal articulations, is apparently somewhat smaller in proportion than in these.

MEASUREMENTS OF ASTRAGALUS.

	Mm.
Greatest length	106
" transverse diameter	68
" " " of proximal trochlea	58
" " " " distal "	59
" antero-posterior diameter of astragalus	55

Calcaneum. — As in *Archæotherium* the calcaneum has a long tuber, which is deeply channeled externally and terminates posteriorly in an enlarged and truncated end, but differs from that of *Archæotherium* in having an open flat surface for the tendo-achillis instead of a decided groove. The fibular facet is divided by an oblique ridge into a superior and an antero-inferior portion. The two facets are confluent,

but at right angles, and are quite similar to those in *Sus* and *Hippopotamus*. The unusual dorso-plantar extent of the distal facet for the astragalus in *Archæotherium*, which was pointed out by Scott, is in *Dinohyus* fully as great. The latter facet is confluent with the lateral facets for the cuboid, and only separated from the distal facet for the same bone by a rounded angle, which is confined to the anterior half of the distal facet. The distal facet for the cuboid is divided into two parts: an anterior, which is plane; and a posterior, which is obliquely concave antero-posteriorly, and is carried high up upon the tibial face to accommodate the corresponding facet of the prominent plantar hook of the cuboid. Above the cuboid and distal astragalar facets there is on the fibular face a deep excavation, which is bounded superiorly by the fibular and sustentacular facets and posteriorly by the heavy border of the tuberosity. The sustentacular facet is quite large and is slightly convex transversely and concave in the dorso-palmar direction.

MEASUREMENTS OF CALCANEUM.

	Mm.
Greatest length	188
Length of tuber	100
Greatest antero-posterior diameter at fibular facet	82
" transverse diameter at sustentacular facet	60

Navicular. — The proportions of the navicular are different from those in the Oligocene genus, which fact is due to the relatively smaller transverse and greater antero-posterior diameters in *Dinohyus*. The articulation for the astragalus is divided by a broad rounded ridge, which is evenly convex from side to side, deeply concave antero-posteriorly, and terminates in elevated and rounded borders dorsally and palmarly. The fibular portion of the astragalar facet is rapidly deflexed externally and terminates abruptly at the fibular angle, while the tibial portion is gently concave transversely and greatly concave antero-posteriorly. The fibular face has three facets for the cuboid, two dorsal and one palmar, as in *Archæotherium*. There is apparently a tendency toward coössification between the navicular and cuboid, as the articulating facets are reduced and the surfaces very rugose throughout. The dorsal face is plane except the rugose and sharp fibular angle which abuts against the cuboid. On the anterior portion of the tibial face the bone is convex vertically, and more so posteriorly. This convex portion is suddenly succeeded by a prominent and rugose area for muscular attachments.

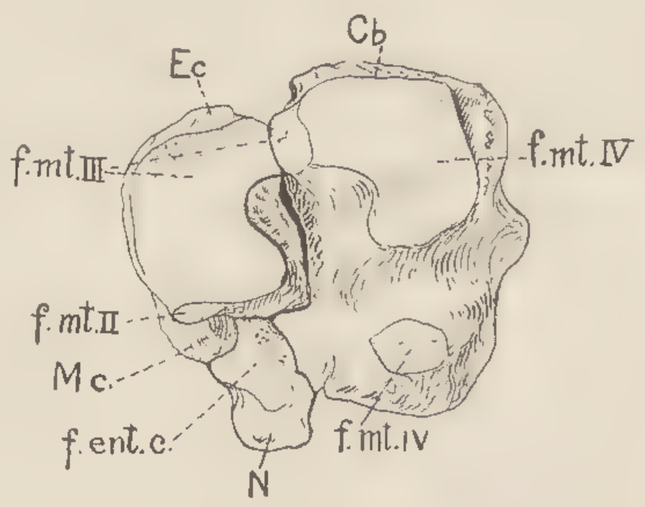


FIG. 79. Distal View of Tarsus of Left Pes of Type of *D. hollandi* Peterson. ½ nat. size. *f* = facet. *Ec* = ecto-cuneiform. *Mc* = mesocuneiform.

The plantar hook is quite prominent and extends well below the distal facets, while in *Archæotherium* it is much reduced, and is, as Professor Scott states, "hardly more than a roughened ridge." The anterior portion of the distal face is taken up by the facet for the ectocuneiform. The latter facet is divided into two areas by fibular and tibial sulci leaving a narrow isthmus midway between the two. The small facet for the mesocuneiform, on the tibial angle in *Archæotherium*, is entirely absent in *Dinohyus*. Another interesting difference in *Dinohyus* is seen in the very much less prominent tubercle on which the facet for the entocuneiform is located; the facet being almost on the same level with that for the ectocuneiform, and saddle-shaped, with the posterior margin deflected on the base of the plantar hook.

The navicular of *Entelodon magnum* (**38,** Pl. XXVII, figs. 34 and 37) is relatively shorter antero-posteriorly, and has a less developed palmar hook than in *Dinohyus*. In *Sus* the navicular is quite different, being broad and articulating distally with the three cuneiforms, as is also the case in *Hippopotamus*. In the latter genus, however, the navicular has no palmar hook, and the articulating surface between the navicular and cuboid is situated near the palmar face.

Measurements of Navicular.			Mm.
Greatest anteror-posterior diameter			73
"	transverse	"	41
"	vertical	" anteriorly	33
"	"	" posteriorly	55

Entocuneiform.— Unfortunately the entocuneiform is lost in the type. Judging, however, from the space on the navicular, and cuneiform when in position, this bone was of considerable height, rather compressed transversely and antero-posteriorly, and in general apparently somewhat different from that in *Archæotherium*.

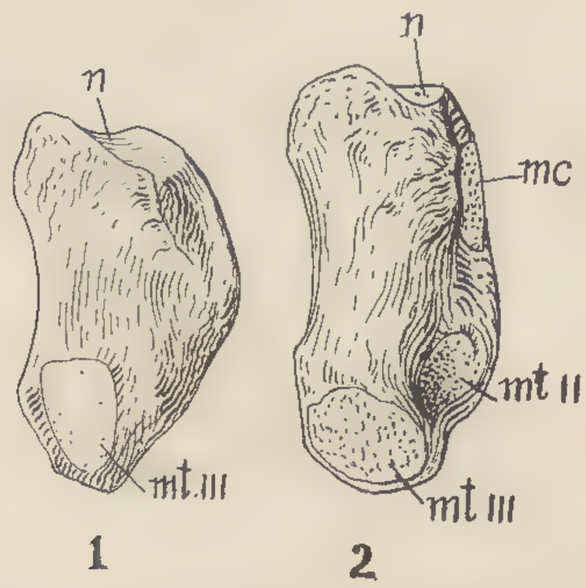


Fig. 80. (1) External View of Right Entocuneiform of *A. ingens* Leidy (Princeton Museum, No. 10885). (2) Same View of Corresponding Bone in *D. hollandi* Peterson (Carn. Mus. Cat. Vert. Foss., No. 2139a).

An entocuneiform of *Dinohyus* (No. 2139a, Carn. Mus. Cat. Vert. Foss.) which was found in quarry No. 1, section 20 (See plan of quarry, Pl. LIV), is of an animal of approximately the same size as the type specimen. The bone differs somewhat from the corresponding bone in *Archæotherium*, being dorsally less produced and more developed in the palmar direction; it is not pointed distally, and its navicular articulation is less oblique. It is further to be observed that there are two facets, one near the proximal end for the

mesocuneiform (fig. 80, mc.), and another small one near the distal end for Mt. II. These are not present in *Archæotherium ingens* (the Princeton specimen). The distal fibular angle of the bone under description is entirely taken up by a large facet, which is slightly convex in all directions, and articulates with a corresponding facet on the palmar process of Mt. III. The bone as a whole has a great vertical diameter, while antero-posteriorly and transversely it is rather compressed, especially in the latter diameter.

Scott (**78,** p. 316) has already stated that the entocuneiform has not yet been found in connection with *Anthracotherium* or with *Entelodon.* In *Sus* the entocuneiform is larger distally than proximally, the palmar tubercle is very prominent and the bone as a whole is altogether different from that in *Archæotherium* or *Dinohyus*, having a large and very prominent articular facet for Mt. II. In *Hippopotamus* the entocuneiform is also heavier, and broader than in the latter genera.

Mesocuneiform. — The mesocuneiform is entirely ankylosed with the ectocuneiform, but its outline, especially on the palmar and tibial angle, is clearly defined (Fig. 79, Mc.). There is, however, no articular facet on the proximal end for the navicular as in *Archæotherium* and there is no facet for Mt. II, but on the proximal fibular angle is a facet for the entocuneiform.

Ectocuneiform. — The ectocuneiform is of considerable size and C-shaped in general outline viewed distally or proximally. The entire proximal face is occupied by the facet for the navicular, and the distal face is taken up by the facet for Mt. III. On the palmar tibial angle of the distal face is a very minute articular surface for Mt. II. The fibular face is very rugose back of the facet for the cuboid, which is located near the dorsal face and occupies the entire vertical diameter of the bone; there is no facet for the cuboid on the proximo-palmar angle, as in *Archæotherium.* In this respect the ectocuneiform of *Dinohyus* is more like that in some peccaries, while in *Hippopotamus* the ectocuneiform articulates with the cuboid only by the large palmar-fibular facet. The antero-posterior diameter of the facet on the distal face for Mt. III is proportionately greater than in *Archæotherium,* and, as in that genus, the facet is in its dorsal portion obliquely convex from side to side, and near the plantar region obliquely concave antero-posteriorly. The fibular border of the facet is deeply emarginated by a sulcus.

MEASUREMENTS OF ECTOCUNEIFORM.

	Mm.
Greatest antero-posterior diameter including mesocuneiform	52
" transverse diameter	32
" vertical "	28

The general outline of the ectocuneiform of *Entelodon magnum* (**38,** Pl. XXVII,

figs. 34, 35, 37) is quite similar to that of *Dinohyus*, but the distal articulation is interrupted on the fibular angle and it is plainly seen from the figure that Mt. III, did not come in contact with the cuboid as in *Dinohyus*.

Cuboid. — The cuboid is relatively large and reveals some interesting and important differences from that of the earlier types. The articular facets for the calcaneum and astragalus occupy the proximal end in nearly equal proportions, the former facet being slightly wider,[56] which is directly the opposite of what is the case in *Archæotherium ingens*, where the astragalar facet is the larger of the two. The cuboid of the type of *Boöchœrus humerosus* more nearly approaches that of *Dinohyus* so far as the two specimens can be compared. The astragalar facet of the present genus is plane transversely, deeply concave antero-posteriorly, and the articular surface is confined to the anterior and posterior parts, with an interrupted median area twelve millimeters long. A deep pit is located on the fibular side of this interrupted sinus, which separates the calcaneal and astragalar facets at this point. The calcaneal facet is less interrupted than that in *Archæotherium*, as described by Scott, and continues obliquely from in front upward and backward, terminating near the summit on the postero-tibial angle of the ascending palmar hook. The tibial border of the dorsal face is heavy and very rugose; the fibular angle is also prominent and abruptly convex antero-posteriorly. The tibial face is rugose and in addition the dorsal facet for the navicular has developed a projecting ledge[57] so that together with the palmar facet, which also occupies a similar though much larger ledge, the cuboid and navicular bones are very strongly interlocked. Below the navicular facet near the dorsal angle is a small facet with square outlines, which articulates with the ectocuneiform. The latter bone was undoubtedly connected posteriorly by cartilage only, as the corresponding surfaces on the two bones are very rugose with no distinct facets, such as are found in *Archæotherium ingens*. Immediately below the facet for the ectocuneiform there is a third facet on the tibial angle.[58] This facet articulates in a prominent and quite important manner with a process of Mt. III which extends above the head of Mt. IV similar to, though less prominent than, that in the manus (figs. 70, 78). These articulations are not present in the peccary, *Sus*, *Hippopotamus*, or *Entelodon magnum*, but on Mt. III in *Archæotherium* there is a very slight indication

[56] On page 448 (38) Kowalevsky says that the cuboid of *Entelodon magnum* has a narrower facet for the astragalus than for the calcaneum, which is also well shown in his illustrations (Pl. XXVIII).

[57] In *Boöchœrus humerosus* this projecting ledge is more developed than in the Princeton specimen from the Oligocene, but is not so prominent as in *Dinohyus*.

[58] In the type of *Boöchœrus humerosus* this facet is not present on the cuboid, but in a smaller individual from the green sandstone (middle beds) of the John Day formation (Yale Museum No. 12765; Collector, L. S. Davis, 1875) this facet is fairly well developed on the cuboid.

of a facet on the fibular angle of the head, which is quite prophetic of the conditions found in *Dinohyus*. The anterior portion of the distal face is taken up by the facet for Mt. IV, that for Mt. V being entirely absent in the type. The palmar face is greatly excavated above the hook; the latter is very prominent and covers the entire lower portion of the palmar face. Distally there is on the tibial angle a facet of considerable size for the palmar process of Mt. IV.

The vertical diameter of the cuboid is relatively less than in the Princeton specimen, which in this respect as well as in the deeper tendinal sulcus on the fibular side of the Carnegie Museum specimen, seems to agree more nearly with *Entelodon magnum* (**38,** pp. 448–449, Pl. XXXVII, figs. 34, 35, and 36). In the latter species the facet on the palmar hook for the palmar process of Mt. IV is absent, and the facet for Mt. V on the fibular-distal angle is present, just the reverse of what appears in *Dinohyus*, in which there is no facet for Mt. V, and there is a facet present on the palmar hook for Mt. IV.

MEASUREMENTS OF CUBOID.

	Mm.
Greatest antero-posterior diameter	70
" transverse "	50
" vertical " anteriorly	55
" " " posteriorly	71

Metatarsal II. — The second metatarsal is reduced to a very small oblong nodule about half the size of Mt. II in the Princeton specimen. The nodule is held in place chiefly by the distal end of the entocuneiform, for which it has an articulating facet of considerable size on the palmar face. On the proximal tibial angle is a small facet for the ectocuneiform.

MEASUREMENTS OF SECOND METATARSAL.

	Mm.
Greatest length	22
" transverse diameter	13
" antero-posterior diameter	7

Metatarsal III. — The third metatarsal is larger and slenderer than Mc. III, but the articular facets for Mt. IV on the third metatarsal are surprisingly similar to the corresponding facets for Mc. IV. Thus the fibular angle of the head rises to a prominent tubercle which overlaps the head of Mt. IV and articulates with the cuboid in much the same manner in which Mc. III articulates with the unciform. This character of the pes seems to be a modification perhaps brought about since Oligocene times, as the genus *Archæotherium* has only a very faint suggestion of a facet for the cuboid, and has the fibular angle of the head of Mt. III only very

slightly higher than the tibial angle.[59] The proximal facet for the ectocuneiform is slightly concave transversely in the dorsal region, and convex antero-posteriorly in the palmar region to conform with the facets of the ectocuneiform already described. On the postero-fibular angle of the head is a very minute facet which articulates with Mt. II. Below this facet is a rugose shallow channel, which receives the second metatarsal. The palmar process is strongly developed, and, as in *Archæotherium*, bears three facets; the one on the tibial side is for the entocuneiform, the one on the fibular side is for Mt. IV, and the one on the palmar end is for a large sesamoid. The facet for Mt. IV, which is near the dorsal face is larger and more pronounced in *Dinohyus* than in the Princeton specimen. The shaft is quite flat, long, and slender on the palmar and fibular faces, round on the tibial and dorsal faces, and is similar to that of *Archæotherium*, except for its greater rugosity on the fibular face, which is a marked character, showing a tendency toward the coössification of the two functional digits in *Dinohyus*. The large tubercle which is developed on the fibular border of the dorsal face just above the trochlea in *Archæotherium*, is in *Dinohyus* developed into a swollen area which occupies the entire dorsal face of the shaft, causing a deep depression distally. This depression is the superior boundary of the distal trochlea. The latter is, as in *Archæotherium*, rather low and narrow. The carina, which is confined principally to the plantar side, is plainly indicated on the dorsal face by a faint ridge, which continues to the extreme proximal border of the articulation. On either side of the carina is a shallow depression, which causes a slight lateral convexity in the tibial and fibular portions of the trochlea.

MEASUREMENTS OF THIRD METATARSAL.

	Mm.
Greatest length	240
" antero-posterior diameter of head	55
" transverse " "	40
Antero-posterior diameter of shaft medially	30
Transverse " " "	30
" " " trochlea	40
Antero-posterior " " "	45

Metatarsal IV. — The fourth metatarsal is of very nearly the same length and thickness as the third. The head does not rise as high as that of the third, but the palmar process is, as in *Archæotherium*, longer than that of the third metatarsal. Dorsally the articular facet for the cuboid is slightly concave in all directions and rises into an antero-posterior convexity in the palmar region. There is a large facet for the cuboid on the end of the palmar process; the tibial face of the process is

[50] Some species of the John Day formation more nearly approach *Dinohyus* in the matter of the articular facets of the cuboid and Mt. III.

occupied by the facet for Mt. III; and immediately behind and at almost right angles is a third facet, which corresponds to that on Mt. III and which supports a palmar sesamoid. There is no evidence of a facet for Mt. V on the fibular angle of the head. Dorsally the shaft is quite flat on its dorsal, tibial, and fibular faces, while the palmar face is unevenly rounded. Towards the distal end the shaft is more cylindrical, the palmar face being by far the flattest. Distally the bone is similar, including the trochlea, to that of the third metatarsal.

MEASUREMENTS OF FOURTH METATARSAL.

	Mm.
Greatest length	237
" antero-posterior diameter of head	59
" transverse " "	41
" " " shaft medially	28
Antero-posterior " " " "	32
" " " trochlea	33
Transverse " " "	37

Metatarsal V. — Judging from the total absence of facets for the fifth metatarsal on the cuboid and Mt. IV it would seem that this element is entirely wanting in *Dinohyus*. There is, however, a minute scale-like eminence on the fibular angle on Mt. IV, which may, or may not, represent the fifth metatarsal.

A water-worn fragment of a fourth metatarsal which I refer to *Dinohyus* (No. 1927, Carn. Mus. Cat. Vert. Foss.) was found in the Agate Spring Fossil Quarry, No. 1, where the type of *Dinohyus* was found. On the postero-fibular angle of the facet for the cuboid of this metatarsal the articulation is flexed downward in such a manner as to suggest the presence of a small fifth metatarsal in this individual.

Palmar Sesamoid. — The palmar sesamoid is a large bone, triangular in outline, compressed antero-posteriorly, and much expanded, especially in the tibial and distal directions. The palmar surface is rugose and on the dorsal face near the fibular angle are two facets for the third and fourth metatarsals described above. There are facets on the palmar processes of the metatarsals in *Archæotherium* which indicate the presence of similar sesamoids.

MEASUREMENTS OF PALMAR SESAMOID.

	Mm
Greatest vertical diameter	38
" transverse "	32
" antero-posterior diameter	12

Phalanges. — The proximal and median phalanges are proportionately longer and narrower than those of the manus; otherwise they are similarly depressed antero-posteriorly and expanded transversely. The articulation for the metatarsal

on the proximal phalanx is divided into two parts by a faint groove, which extends across the face and terminates in the deep plantar notch. On either side of the latter are facets on the extreme plantar angle of the proximal end which abuts against the sesamoids. The distal trochlea is, as in the manus, simply convex antero-posteriorly and concave transversely. The median phalanx is quite similar to that in the manus. The ungual phalanx is short, high, and somewhat compressed. They suggest strongly those of the recent camels though proportionally larger.

MEASUREMENTS OF PHALANGES.

Proximal phalanx.

	Mm.
Greatest length	78
" transverse diameter of proximal end	42
" antero-posterior " " " "	35
" transverse " " distal "	37
" antero-posterior " " " "	23

Median phalanx.

	Mm.
Greatest length	57
" transverse diameter of proximal end	36
" antero-posterior " " " "	35
" transverse " " distal "	34
" antero-posterior " " " "	30

Ungual phalanx.

	Mm.
Greatest length	39
" vertical diameter, approximately	30
" transverse "	27

Sesamoids. — The sesamoids, though of considerable size, are much smaller than those of the manus. They are heaviest anteriorly and taper to an obtuse hook posteriorly. The dorso-proximal angle carries an articular surface which abuts against a corresponding surface on the proximo-plantar angle of the first phalanx described above.

RESTORATION OF DINOHYUS HOLLANDI.

(Plates LX, LXI.)

The most conspicuous features of the skeleton of *Dinohyus hollandi* are the disproportionately large skull, the long muzzle, the heavy neck, the high withers, and the elongated limbs. Many other characters are impossible to fully appreciate without seeing the skeleton mounted in full relief. The thorax has nearly the same proportions as in *Bos taurus*, but the lumbar region is shorter. In *Sus* the lumbar region is relatively longer than in *Dinohyus*, and the latter genus is, in this

respect, more analogous to the *Hippopotamus*. The sternum is of enormous size and there are osseous sternal ribs present. The fore limbs are powerful and the skeleton in this region is not unlike that of *Bison americanus*. In the region of the fifth, sixth, and seventh cervicals the neck was of enormous vertical diameter.

There are only four lumbar vertebræ present derived from the type and a fragment of the pubis represents all that was found of the pelvis. These parts were found in a pile of fragments left on the edge of the quarry by Mr. Cook who started to excavate in the fall of 1904. The pelvic material, which was found in quarry No. 1 in 1908, is used in this restoration and its anatomical features are thought to be practically correct. The right femur and certain bones of the manus were also found in quarry No. 1 and are here used for the purpose of accuracy. The right cuboid, the entocuneiform and Mt. IV are derived from other individuals. The caudal region is restored throughout.

The skeleton was mounted by Mr. Serafino Agostini of the paleontological staff, to whom much credit is due for the skill he has displayed in his work.

In 1894 Professor Marsh published (**64,** pp. 407–408, Pl. IX) a restoration which is based on rather incomplete material and as a consequence a number of errors occur, some of which were pointed out by Professor Scott in his memoir on "*Elotherium*" (**87,** pp. 320–321). In *Dinohyus hollandi* there are unquestionably fourteen dorsal vertebræ, which were found in a continuous series. The character of the anterior sacral vertebra in comparison with the lumbars present in the type of *Dinohyus hollandi* seems to indicate that there must be two vertebræ missing. Two vertebræ have therefore been inserted (l. 3 and l. 6) which appears justifiable. Furthermore, it is quite evident from Professor Scott's publication (**87**), as well as from my own observations on the same material, that there are six lumbar vertebræ in *Archæotherium ingens*. It would then seem that Marsh (l. c.) was correct as regards the number of presacral vertebræ of his restoration, but made a mistake in the division of the dorso-lumbar series, while Scott's restoration (fig. 9) shows only thirteen dorsal vertebræ. In examining the Princeton specimen it occurred to me that the spines in the posterior dorsal region are too abruptly shortened and that there was probably an additional dorsal vertebra.

In comparing the articulated skeleton of *Dinohyus* with that of *Archæotherium ingens* (see fig. 9) it is at once seen that the former has a relatively larger head, shorter and heavier body, higher withers, and a shorter pelvis. Furthermore, the sagittal crest is higher posteriorly, which indicates a greater vertical diameter of the neck immediately back of the skull. Thus, it is seen that the Miocene genus had a relatively heavier neck than its Oligocene predecessor.

MEASUREMENTS OF THE RESTORED SKELETON.

	Cm.
Length from premaxillary of skull to the posterior end of ischium	288
Length of cervical region	51
" " dorsal "	91
" " lumbar "	38
" " sacral " approximately	12
" " sternum	52
Height at 2d dorsal vertebra	177
" at superior border of ilium	140
" " end of ischium	113

A model in full relief of *Dinohyus hollandi,* a photograph of which is given on Plate LXII, has been made by Mr. Theodore A. Mills under the direction of the writer. An examination shows that this figure is at variance with the painting prepared by Mr. Charles R. Knight under the direction of Professor Henry Fairfield Osborn (**72a,** p. 713). *Archæotherium* is represented in that figure as having long stiff bristles on a very broad neck, with the ears as in the *Suinæ,* and as having heavy pendant wattles hanging from the bony tubercles of the inferior margins of the mandibles. Although the bristles and the broad neck shown in Knight's illustration may be correct, there is reason to believe that the ears were placed lower down and were more drooping, judging from the position of the external auditory meatus, which in the true pigs is directed upward and slightly outward, while in those American genera of the Entelodontidæ, in which this part is known, the auditory meatus is directed nearly horizontally outward and has a prominent overhanging border on the upper side formed by the squamosal. In the restoration by Mr. Mills the dependent processes on the inferior border of the mandibular rami of *Dinohyus* are represented as supporting muscles, it being believed by the writer that these processes, at least in the genus *Dinohyus,* existed for the attachment of muscles in order to give required strength to this portion of the head. The model, of which the figure is given, is of course to a certain extent conjectural, but is believed by the writer to very fairly represent the animal as it was in life, and he takes occasion to compliment Mr. Mills upon the skill which he has shown in carrying out the suggestions made to him.

Conclusion.

While the osteology of at least two genera of this interesting family is now quite completely before us, I make no attempt to present a succession of species, as it seems to me that we have not yet the necessary material in order to satisfactorily study the more detailed questions of the phylogeny of this group. Aymard and Pomel with the extremely limited material representing this family at their com-

mand, were constrained to place it among the living swine, where it has since, with only one or two exceptions (*Subursi* of de Blainville and *Arctodon* of Leidy), generally been placed by different writers. That the family is a "collateral branch" of the Suidæ, which "branched off in early Eocene time" as Marsh says (**64,** p. 406), is from all the evidence at hand unquestionable. "Schlosser has referred the genus [*Elotherium*] to the bunodont division of the family *Anthracotheriidæ*, which family he derives from an Eocene stock common to the *Anthracotheriidæ*, the *Anaplotheriidæ*, the *Hippopotamidæ*, and the *Suidæ*" (**87,** p. 322). Scott says (*l. c.*): "The genus [*Elotherium*] is so far specialized that it implies a long ancestry, not a member of which is, as yet, certainly known, although there are certain Eocene genera, which throw some light upon the problem." Stehlin in his discussion of the dental structure of the *Entelodontidæ* (**90,** pp. 121–123) concludes in a footnote (p. 123) by saying: "jedenfalls liegt die Vorgeschichte der Elotherien noch sehr im Dunkeln." It is apparent that, although we are well acquainted with the general anatomical features of this family, we can for the present at best only speculate in a general way as to the early history of the group. From the work of Schlosser it is plain that he regards the early Tertiary of the Old World as the home of the ancestral line of the *Entelodontidæ*, which may possibly prove to be true, unless "we may suppose," as Matthew has stated in connection with his study of the genus *Ancodon*,[60] "that from a diffusion center in Northern Asia early stages in the evolution of [this] phylum [also] reached Europe," and that the American form reached North America at the beginning of the Oligocene.

As for the known forms in the early American Tertiary there is not one which can properly be regarded as truly ancestral to the family. *Achænodon* of the Bridger, and *A. uintense* of the Uinta are already too far advanced in the modification of their dentition, having but three premolars, while the limbs of *A. uintense* would seem to have retained a more primitive condition, having "four [? functional] digits in the pes" (**72,** p. 105). The suggestive resemblances of the known characters of *Achænodon* found in the Bridger formation, and *A. uintense* of the Uinta, should, I think, be regarded only as pointing to a remote relationship; indeed it would seem that no great violence is done in referring these general resemblances to parallelism, which was no doubt a greater factor in moulding characters than is sometimes realized. The primitive bunodont teeth, the characteristic glenoid cavity of the skull, the expanded zygomatic arches, and the elongated muzzle of these earlier Tertiary forms are not to be dismissed so easily, as they are certainly most suggestive of the *Entelodontidæ*. But, as has been suggested by others (**87,** p. 322) there is no more

[60] Bull. Am. Muesum of Natural History, Vol. XXVI, p. 4, 1909.

reason why we should not expect a parallelism here as well as, for instance, in the odontoid process of the axis, the selenodont molars, the reduction of the lateral digits, and many other features, which have been independently acquired by several distinct lines.

In regard to the ancestry of the *Entelodontidæ* Dr. Herluf Winge (**92a,** p. 134) seems to have reached a somewhat similar conclusion to that of Schlosser. From a study of the dental, cranial, and other skeletal characters of the *Entelodontidæ,* Winge (*l. c.,* p. 141) seems also to think that they perhaps were less in the habit of rooting in the earth than their ancestors and that, instead of the usual plant-food of the Ungulates, which they perhaps entirely excluded, they accustomed themselves to mixed, or flesh-food. In fact Winge (*l. c.,* p. 141) states that the incisors, canines, and premolars served as grasping-tools and weapons similar to those of carnivores ; and (*l. c.,* p. 142) that it is also not altogether unlikely that they lived in a similar manner to that of dogs, preying on live animals, or, when they discovered carcasses, fruits, etc., that they fed on them. That these animals actually seized live animals as their food, as Dr. Winge seems inclined to believe, may well be doubted, while that they fed on carrion and fruits, as well as on plants, is not altogether unlikely.

Lydekker has very suggestively said (**53a,** p. 78) that the "food of the higher selenodont pigs consisted in great part of leaves and grass (which require finer trituration . . .) while their bunodont allies feed, as we know, more generally on roots and tubers, and occasionally on animal matter. Hence it is probable that the muzzles of most of the selenodonts were less elongated than in the true pigs, which require to turn up the soil to obtain nutriment." It has been, I think, quite conclusively shown, by Scott (**87,** p. 278), and also in the description of the dentition of *Dinohyus* in the present paper, that the wear of the lower canines and incisors could not have been caused, in this animal, except by the habit of digging up roots.

The dental structure of *Tetraconodon,* from the Siwalik hills of India, precludes its introduction into the family *Entelodontidæ* and it has quite correctly been placed in a distinct family by Lydekker (**53a,** p. 78). This genus is apparently quite far removed from the *Entelodontidæ* as is *Achænodon* of the American Eocene.

The phyletic and geologic position of the family *Entelodontidæ* may then be expressed in a general way as follows :

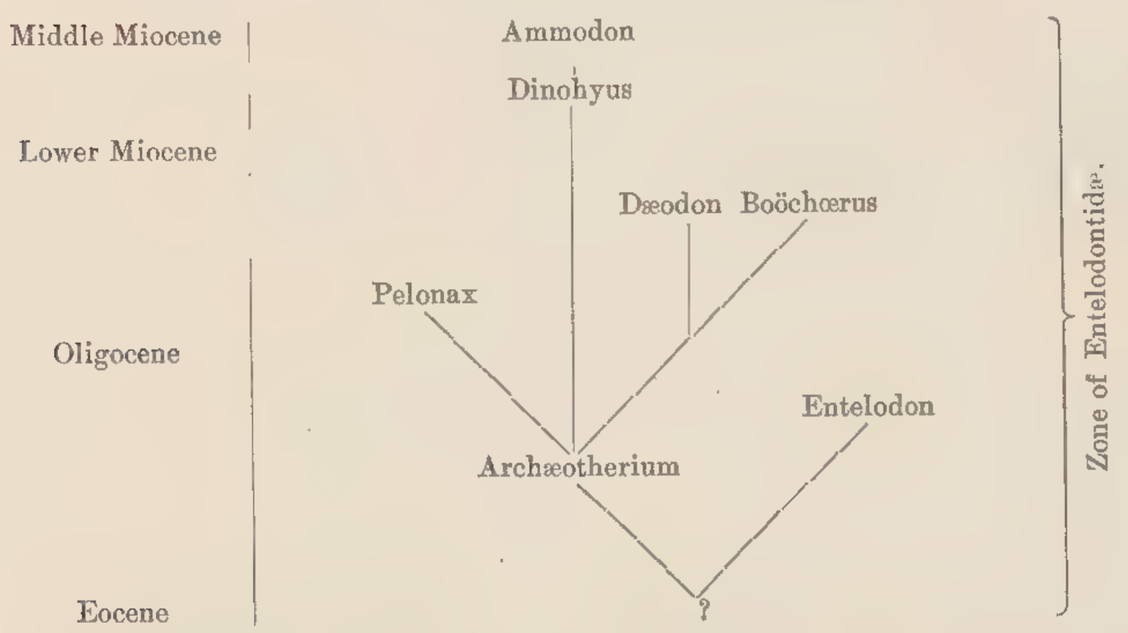


DIAGRAM EXPRESSING THE PHYLETIC AND GEOLOGIC POSITION OF *Entelodontidæ*.

As Pomel (**74,** p. 1085), Leidy (**50,** p. 174), Marsh (**64,** p. 408), Kowalevsky (**38,** p. 450), Scott (**87,** p. 322), Schlosser (**83,** p. 80), and others have shown us, this family has in the pigs and *Hippopotamus* its nearest [61] representatives of the recent forms, while the direct ancestors are yet to be found. In the meanwhile we have seen that during the relatively short geological time in which we are able to trace the family in Europe and America there are certain anatomical differences, indicating lines of divergence. These lines probably point to habits due to the varied environments during the life-history of the group.

We have, for example, in the European genus *Entelodon*, a form with enlarged premolars indicating a diverging step from *Archæotherium*. It has further been pointed out that the base of the skull of *Entelodon* is very greatly different from that of the American forms; and also that the trigon of the lower molars is entirely absent, while in *Archæotherium* it is quite plain in young, but fully adult specimens. *Pelonax ramosum* of the upper Oligocene has tremendously heavy chin-processes, a very prominent angle, and single-rooted first and second lower premolars. *Dæodon* of the John Day formation has no chin-processes at all and has a light angle of the lower jaw; while in the Miocene of Nebraska we have in *Dinohyus* a form with very small chin-processes, and a gentle sweep of the downward projection of the angle approaching what is seen in *Dæodon*. The median upper incisors of *Dinohyus* are distinctly reduced and are in fact sometimes wanting, having been perhaps shed quite early and the alveoli closed up.

In confining ourselves to these characters of the mandible alone and leaving out *Entelodon* whose generic position can hardly be doubted, it would seem that there is a variation of importance, when we consider the fact that all the specimens

[61] The relationship to these recent forms is a very remote one.

found with these parts present in the Oligocene formation have the chin processes present. This character then cannot be regarded as only of sexual importance so far as the Oligocene forms, which are most abundantly found, are concerned. It then remains to be seen whether certain forms like *Archæotherium clavum* with the relatively small and posteriorly placed chin-processes led up to such forms as *Dæodon* or if we will yet find in the lower Oligocene a form minus these protuberances. The discovery of such a form would indicate that the various lines even to quite small details of differences were already well established in older Tertiary time. While the variation in the canine teeth, the dependent processes of the lower jaw, and the jugal of the skull in the different species of the lower Oligocene, may seem comparatively small, they are nevertheless of some importance when it is shown that certain other parts, as for instance the vertebral column, are quite varied. In *Archæotherium ingens* from the lower Oligocene, the neural arches of the dorsal vertebræ are imperfectly pierced by canals, while in *Archæotherium crassum* from the same horizon, the horizontal canals are apparently present as in *Bos taurus*. In *Dinohyus* from the Miocene we know that the neural arches of the dorsals are not only perforated by horizontal canals, but by vertical canals as well; a character which is identical with what is found in *Sus*.

While the geographical distribution of this family in Asia is at present only a matter of speculation, it is clear that Europe and especially North America were occupied by it. Thus we have seen that while their remains are comparatively abundant on the flanks of the Rocky Mountains, evidence of their existence is not altogether wanting in California and New Jersey (" *E. superbum*," *Ammodon leidyanum*). From the lower Oligocene upward, and before the close of the Miocene, then, they occupied certain areas of the North American continent from the Pacific to the Atlantic coasts. Judging from their anatomy, their undoubtedly omnivorous dental structure, their elongated limbs, and their distribution, it is highly probable that these animals were capable of combating adverse conditions when occasion required change. While we know that the representatives of this family continued in America to a later geological age than was recently believed and that there were distinct genera and species during the known existence of the group from the lower Oligocene to the middle Miocene, there is yet much to be ascertained and we are far from having solved the whole history of this interesting branch of the suborder *Artiodactyla*. When a more extensive survey of Asia, especially its northern part, is made, and its Tertiary fauna becomes better known, we probably will be supplied with much valuable information on obscure points in connection with the study of the vertebrate paleontology of the Tertiary formations of the continents of the northern hemisphere.

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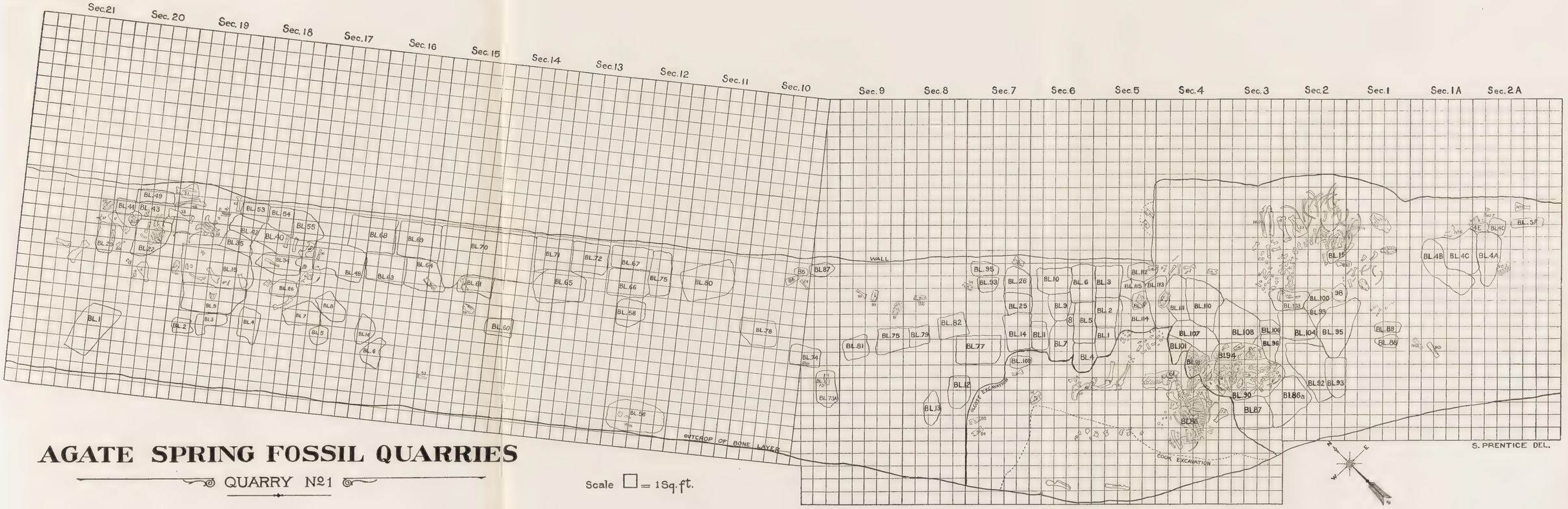
EXPLANATION OF PLATE LIV.

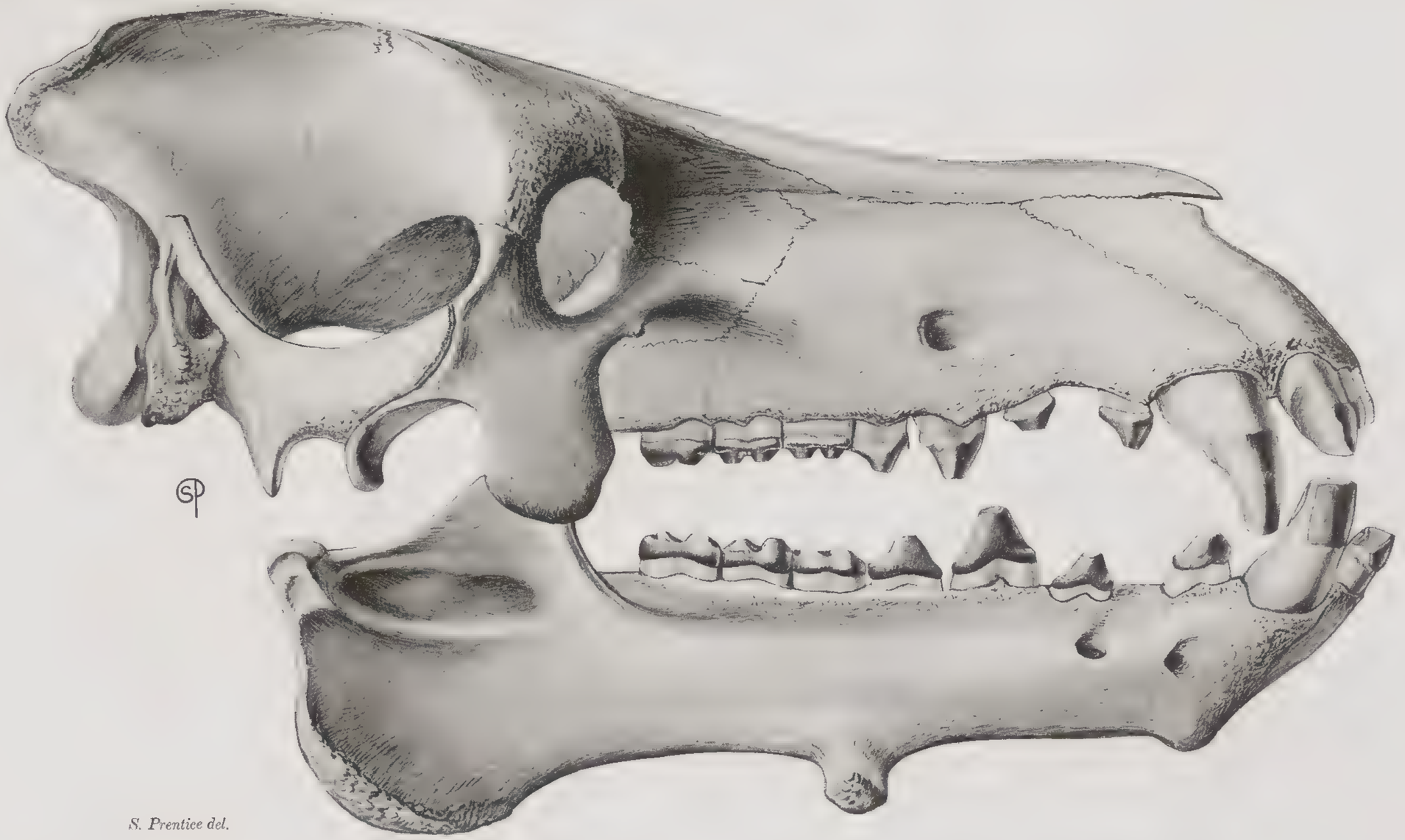
Agate Spring Fossil Quarries. Plan of Quarry No. 1. Bl. = "Block" and associated with numbers indicates relative size of blocks taken out of the quarry. Sections 2A, to 21, indicate relative position of each block and specimen as they were taken out.



AGATE SPRING FOSSIL QUARRIES

QUARRY Nº1

Scale □ = 1 Sq. ft.

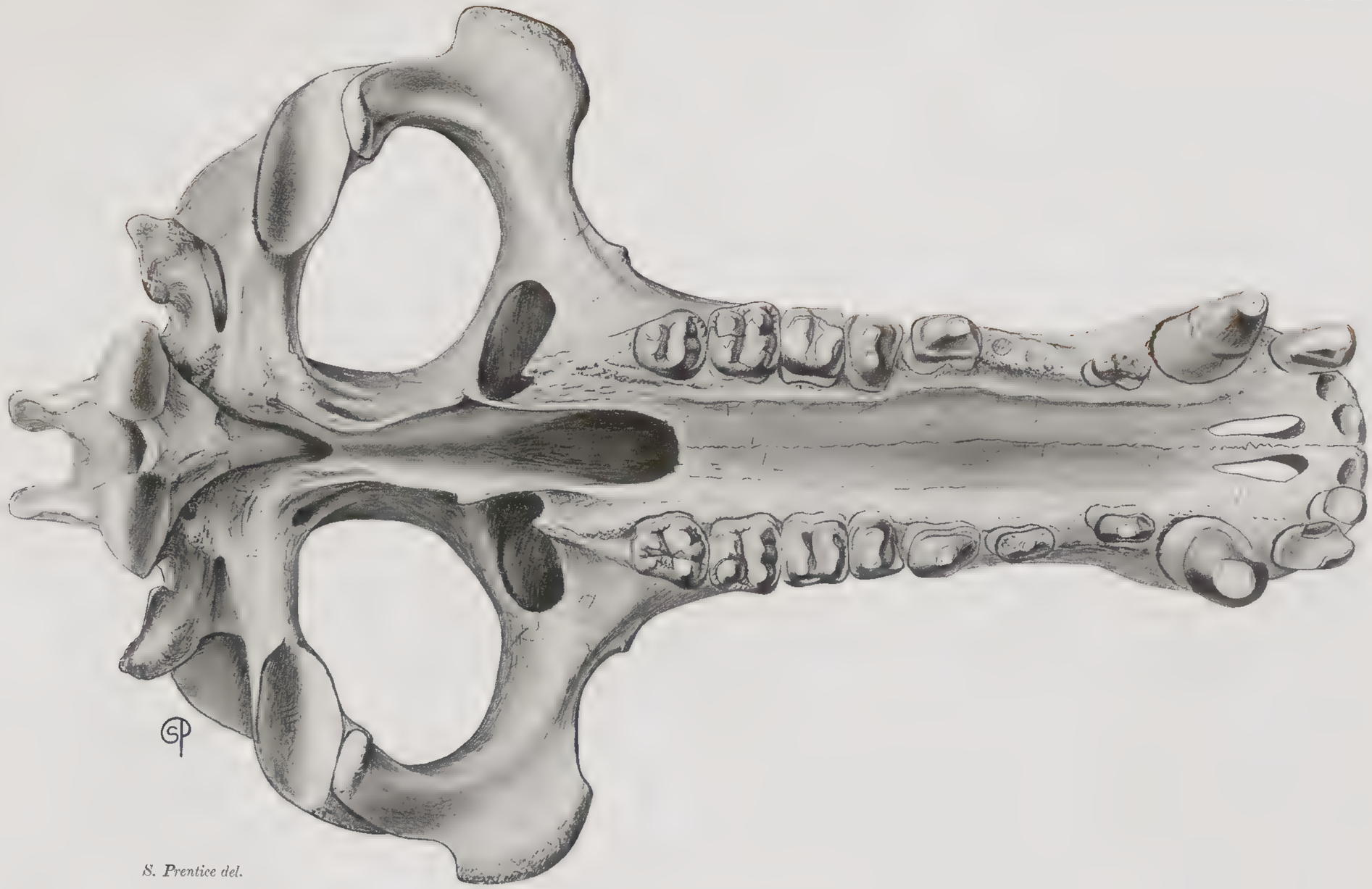


S. Prentice del.

VIEW OF RIGHT SIDE OF SKULL OF *Dinohyus hollandi*, PETERSON. $\frac{7}{23}$ NAT. SIZE. (CARN. MUS. CAT. VERT. FOSS. NO 1594.)

S. Prentice del

SUPERIOR VIEW OF CRANIUM OF *Dinohyus hollandi* PETERSON. $\frac{1}{25}$ NAT. SIZE.



S. Prentice del.

PALATAL VIEW OF CRANIUM OF *Dinohyus hollandi* PETERSON. $\frac{7}{25}$ NAT. SIZE.

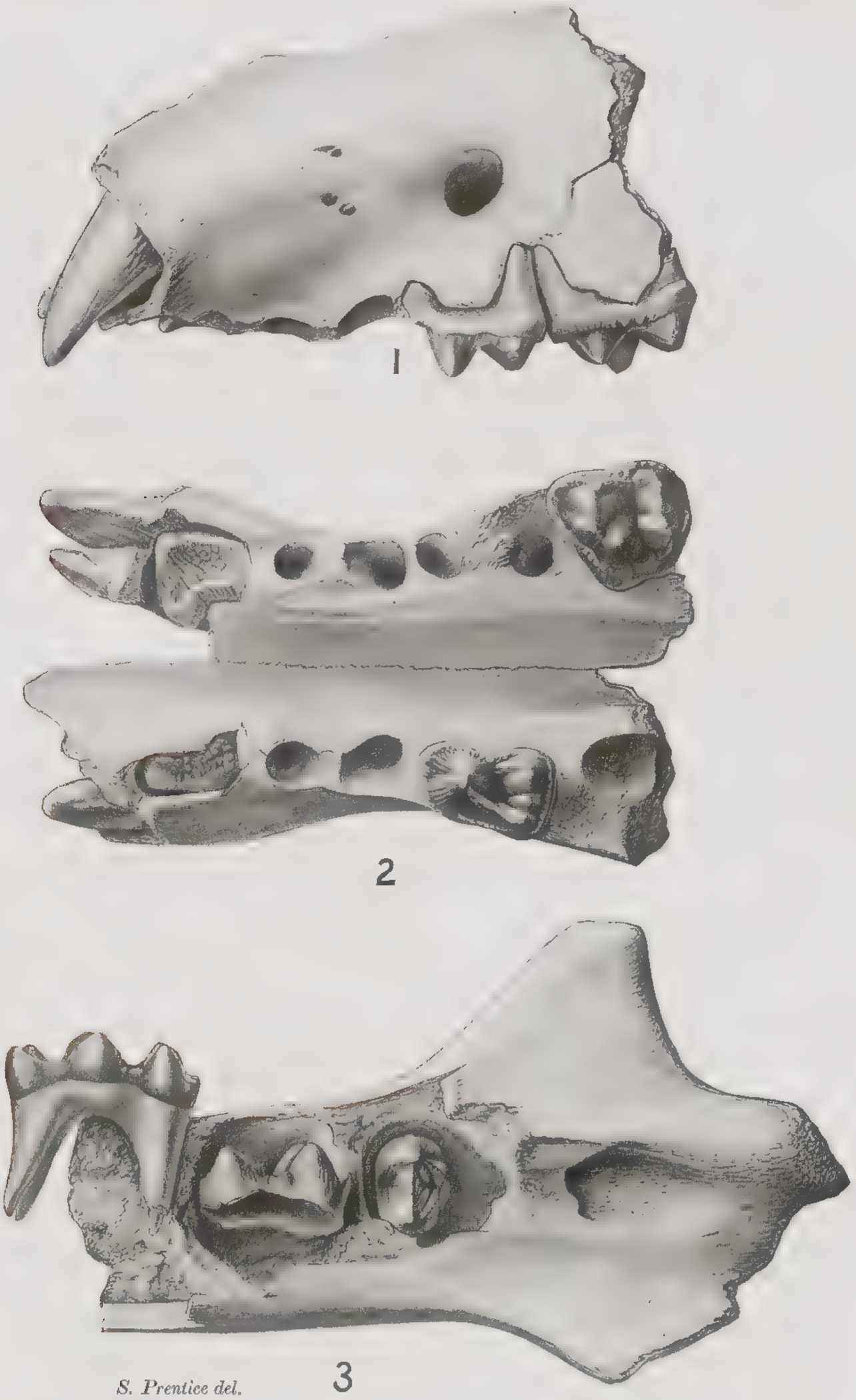
1

2

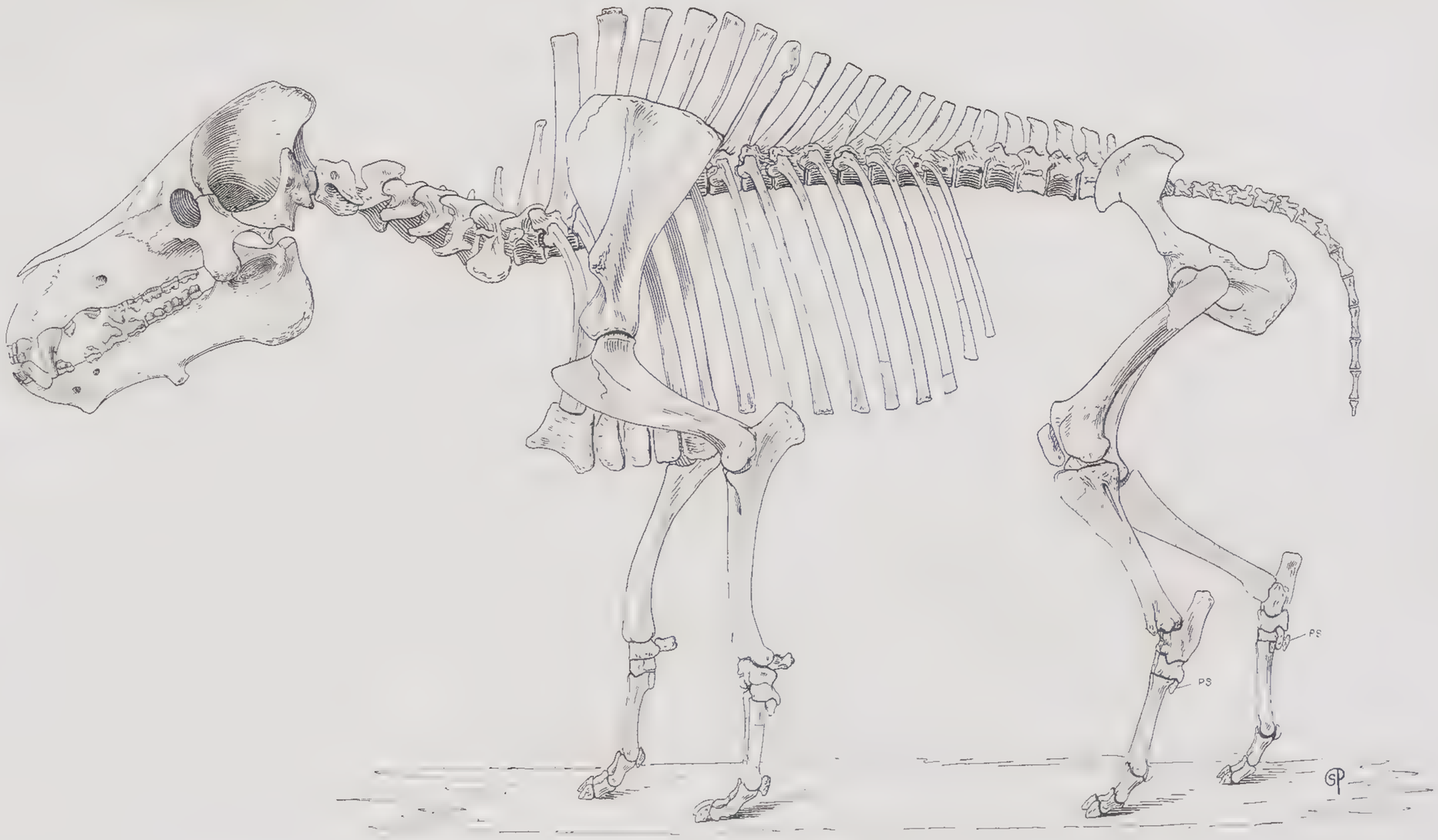
3

S. Prentice del.

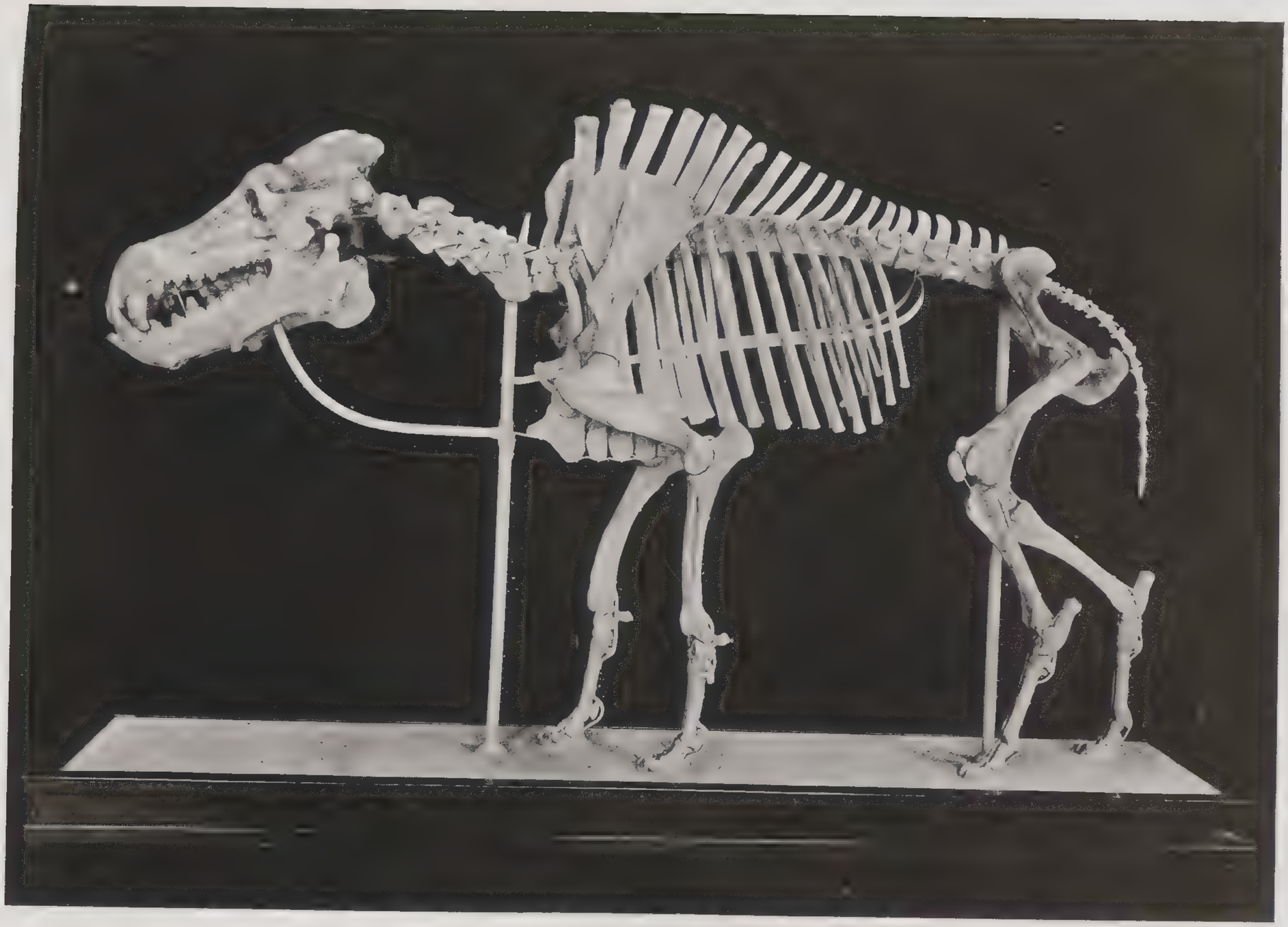
DENTITION OF *Dinohyus hollandi* PETERSON. ½ NAT. SIZE. 1. CROWN VIEW OF UPPER DENTITION OF LEFT SIDE. 2. SIDE VIEW OF LOWER DENTITION OF LEFT SIDE. 3. CROWN VIEW OF LOWER DENTITION OF LEFT SIDE.



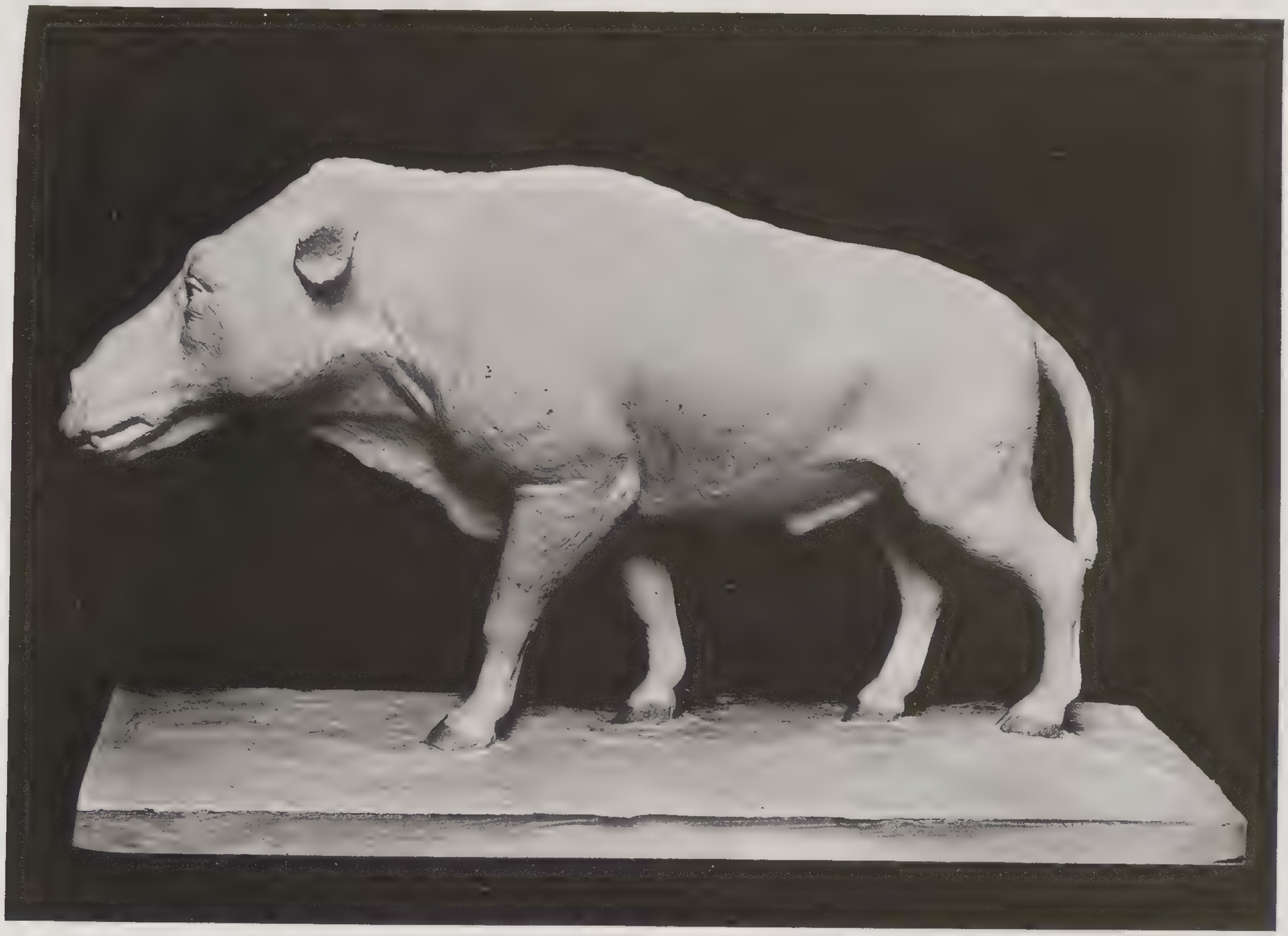
DECIDUOUS DENTITION OF *Dinohyus hollandi* PETERSON WITH PERMANENT DENTITION COMING INTO VIEW. ½ NAT. SIZE. FIGS. 1–2. NO. 2137; FIG. 3, NO. 2137A, CARN. MUS. CAT. VERTEBRATE FOSSILS.



MOUNTED SKELETON OF *Dinohyus hollandi* PETERSON. $\frac{1}{13}$ NAT. SIZE.
(*ps*, Palmar sesamoid.)



PHOTOGRAPHIC REPRODUCTION OF THE MOUNTED SKELETON OF *Dinohyus hollandi* PETERSON. ABOUT $\frac{1}{15}$ NAT. SIZE.



RESTORATION IN RELIEF OF *Dinohyus hollandi* PETERSON. ABOUT $\frac{1}{12}$ NAT. SIZE. MODELLED BY THEODORE A. MILLS UNDER THE DIRECTION OF O. A. PETERSON.

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OF THE

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VOL. IV. NO. 4.

W. J. HOLLAND, EDITOR.

A CATALOG OF THE FISHES OF FORMOSA.

BY DAVID STARR JORDAN AND ROBERT EARL RICHARDSON.

PITTSBURGH.

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MEMOIRS

OF THE

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VOL. IV. NO. 4

A CATALOG OF THE FISHES OF THE ISLAND OF FORMOSA, OR TAIWAN, BASED ON THE COLLECTIONS OF DR. HANS SAUTER.

By David Starr Jordan and Robert Earl Richardson.

In the year 1906 a large collection of the market-fishes of the island of Formosa was made by Dr. Hans Sauter. These were sent to the writers for identification, and were at our suggestion purchased by the Carnegie Museum, in which they are now preserved. A number of duplicates have been presented to the Museum of Stanford University in California.

This collection was obtained in the port of Takao, or Takow, on the southwestern coast of the island of Formosa, called in Japanese Taiwan. It is in excellent condition, and gives a good representation of the market-fishes of Formosa.

For the sake of completeness we have included in this list the fishes recorded by Jordan and Evermann in a paper entitled "Notes on a Collection of Fishes from the Island of Formosa" (Proceedings U. S. National Museum, Vol. XXV, 1902, pp. 315–368), and also the species recorded by Günther, Regan, and others, which are preserved in the British Museum.

We desire to acknowledge the courtesy of the authorities of the United States National Museum, who have permitted us herewith to reproduce the figures of those species, which were given in the paper referred to above. The plates accompanying this article were drawn by Mr. William Sackston Atkinson.

The following species are here described as new to science:

Pristiurus sauteri,
Raja hollandi,
Leptocephalus ectenurus,
Ophichthus evermanni,
Scolopsis eriomma,
Pseudotolithus brunneolus,
Hemipteronotus evides,
Glossogobius abacopus,
Gymnothorax leucostigma.

As noticed by Jordan and Evermann, the fauna of Taiwan bears close relation to that of Southern China, and also to that of Southern Japan. In the main, however, the fauna is tropical, a large proportion of the species being found in India and the Philippines. The coral-reef species of Formosa are still unknown, except as recorded from the Riu Kiu Islands, which lie to the northward. Few of the species of Central Japan extend their range southward to Taiwan.

Family SCYLLIORHINIDÆ.

1. **Cephaloscyllium umbratile** Jordan & Fowler.

One specimen from Takao, measuring two feet to end of tail.

2. **Pristiurus sauteri** sp. nov. (Plate LXIII, Fig. 1.)

Body not so slender as that of *Pristiurus eastmani* of Japan; head measured to first gill-opening 6 in total length; depth equal to half distance between tip of snout and fourth gill-opening; snout 2¾ in head; front and back edge of each nostril with a pointed flap; these crossing and closing the nostril at middle; entire width of one nostril equal to the internarial space and almost exactly twice the distance of the inner angle of nostril from mouth; width of mouth slightly greater than length of snout and about equal to interorbital space; teeth each with a median long cusp, on either side of which is a cusp of about half its length; each short cusp may or may not have at its base one or two rudimentary cusps; roof of mouth and tip of tongue with minute prickles; spiracles directly behind eye and distant slightly less than their diameter from it; distance from first to fifth gill-opening equal to distance from spiracle to first opening.

Scales minute, each with a strong central cusp, on each side of which is a rudiment, and with an evident median keel; upper edge of tail with a low keel beingning a little less than two eye-lengths behind second dorsal and extending backward to merge into upper lobe of caudal fin; this keel armed on each side with a row of enlarged scales, between which are four rows of ordinary scales.

First dorsal originating over back of base of ventrals, its base reaching nearly an eye-length farther back than base of ventrals; origin of second dorsal a little behind middle of base of anal; second dorsal only a little, but distinctly, smaller than first; free edges of both dorsals nearly straight; caudal with a shallow notch on under side near tip; width of ventral base equal to distance in front of eye to middle of spiracle; inner distance between bases of pectorals equal to length of eye; free margin of pectorals straight or slightly concave; tip of anal a little short of a vertical from tip of second dorsal.

Color uniform brownish on back and upper part of sides, paler below; first and second dorsals black on upper anterior half, white on posterior third; upper lobe of caudal with a broad blackish margin; pectorals dark brownish anteriorly above, whitish behind and on free margin; ventrals and anal with rather indistinct pale margins.

Six specimens, twelve to fourteen inches long, from Takao. The species is apparently close to *Parmaturus pilosus* Garman from Japan, but it seems to differ from the latter in the insertion of the first dorsal and in the coloration of the fins.

We agree with Regan that *Parmaturus* is not recognizably distinct from the European genus *Pristiurus*.

Family ORECTOLOBIDÆ.

3. **Chiloscyllium indicum** (Gmelin).

Formosa (Jordan & Evermann).

FIG. 1. *Chiloscyllium indicum* (Gmelin). (After Jordan & Evermann, Proc. U. S. N. M, Vol. 25, p. 317.)

4. **Orectolobus japonicus** Regan.

Formosa (Regan).

Family CARCHARIIDÆ.

5. **Scoliodon walbeehmi** (Bleeker). (Plate LXIII, fig. 2.)

(Native name *Soo hii*, = "sandfish.")

One specimen from Takao, thirty-five inches long to end of tail. Another specimen, eleven inches long, and figured by us, may represent a different species, having the mouth characters of *S. walbeehmi*, but the tail much longer. Its description follows:

Head 5 times in total length; depth 5 in length to base of ventrals; eye $2\frac{3}{4}$ in interorbital space, which is contained $2\frac{1}{6}$ in head (to first gill-opening); length of snout from front margin of mouth equal to distance from back of orbit to second gill-opening; a short labial groove, equal to width of nostril, on upper jaw; lower

jaw with a groove a little more than half that length; distance between nostrils a little more than half interorbital space and less than twice eye; teeth not yet appearing through the gums; scales apparently as usual in *Scoliodon,* but little developed in the specimen, the body being smooth in places when rubbed forward with finger; base of first dorsal equal to distance from eye to first gill-opening, its middle almost exactly half-way between ventrals and last gill-opening; second dorsal inserted over back of anal; caudal noticeably longer than in specimens of *S. walbeehmi* of the same size, the distance from the pit to the notch on under side near tip equal to length of head to second gill-opening; posterior margin of pectoral slightly concave; color bluish-olive above, pale below; free margin of first dorsal and upper and lower edge of caudal black.

The above description is based on a single young specimen, eleven inches long apparently very recently a fœtus (see figure), from Takoa. Except for the smoother body, absence of teeth and longer tail (all fœtal characters?) the specimen does not seem to differ from specimens of *Scoliodon walbeehmi* from Manila of the same size. One specimen of *S. walbeehmi* from Manila one-fourth inch shorter in total length has the scales evident over whole body and fins, the teeth well through, and the umbilical scar absorbed. If our specimen is a recent fœtus of this species, as it may be, it is then necessary to assume either that it is somewhat overgrown for its age, or that a marked shortening up of both body and tail occurs at about the time the teeth appear and the scales attain their full development.

6. **Triakis scyllium** Müller & Henle.
   Formosa (Jordan & Evermann).

7. **Galeus japonicus** Müller & Henle.
   Formosa (Jordan & Evermann).

Family SPHYRNIDÆ.

8. **Sphyrna zygæna** (Linnæus).
   Formosa (Jordan & Evermann).

Family ALOPIIDÆ.

9. **Alopias vulpes** (Gmelin).

Two specimens from Takao, ten and one-half inches to base of lower caudal lobe; twelve inches to tip of tail.

Family SQUALIDÆ.

10. **Squalus japonicus** Ishikawa, (?).
    A fœtus from Formosa (Jordan & Evermann).

Family RHINOBATIDÆ.

11. **Rhinobatus schlegeli** Müller & Henle.

Formosa (Jordan & Evermann).

Family RAJIDÆ.

12. **Raja hollandi** sp. nov. (Plate LXIV.)

Interorbital space $3\frac{2}{3}$ in distance from eye to tip of snout; width of mouth $1\frac{3}{5}$; length of first dorsal $1\frac{1}{3}$ times, caudal (upper lobe) $1\frac{1}{2}$ times interorbital space; length of eye nearly equal to interorbital space.

Body rhomboid, broad, the width of the disk one-fourth greater than its length; head not large and snout not much produced, though ending in a small point; anterior margin of disk full (slightly convex) in front of and lateral to eyes, weakly concave in outer half; distance between eye and margin of disk twice interorbital space; mouth scarcely undulate, the angle made by meeting lower jaws about 75°–80°; teeth small, rounded, about forty-five rows in upper jaw: nostrils large, separated a distance about equal to width of mouth, their length (antero-posterior) about one-half width of mouth, with which nostrils are confluent; posterior margin of nasal flaps fringed; interorbital space concave; a supraorbital semi-circlet of eight or ten short spines, directed backward; spiracles a little wider than half length of eye, directly posterior to eye's outer half; width of gill-opening about $2\frac{1}{2}$ in length of eye; body and head smooth except for the supraorbital spines and a single median dorsal spine a little farther behind eyes than their distance apart; back and sides of tail with five rows of short backwardly directed spines; under edges of snout, to a point even with outermost gill-opening, beset with numerous minute spines.

Dorsals separated a distance $1\frac{1}{3}$ times length of base of first dorsal; second dorsal separated from caudal a distance three-fifths length of base of first dorsal; total length of tail from axilla of ventrals equal to seven-tenths width of disk; angle of pectorals falling a little in front of midway of length of disk; ventrals deeply notched, distance from ventral notch to posterior tip of ventral about four times in length of tail.

Color in spirits brown above, lighter bluish to greenish beneath; back and all upper surface except tail and snout densely covered with small black specks about the size of coffee grains; snout translucent, its upper surface appearing whitish in reflected light; the numerous mucus pores of under side of snout and sides of mouth each surrounded by a circle of black; tail brownish above (perhaps faintly mottled), paler with some dusky underneath.

Described from a single specimen, female, from Takao; length of disk eight and one-fourth inches, width ten inches, tail seven inches. It is named for Dr. William J. Holland, Director of the Carnegie Museum.

Family DASYATIDÆ.

13. **Dasyatis bennetti** (Müller & Henle) (?). (Plate LXV.)

(*Trygon carnea* Richardson, Ichth. Chin., 197, fœtus.)

One specimen from Takao with disk fourteen inches long and thirteen inches wide, and tail thirty-one inches long, we refer provisionally to this species, which was described from Hong Kong. Front margins of pectorals converging at an angle of 65°; sides of the short tip of snout meeting at nearly a right angle; tail with a low black cutaneous fold on under side, originating under the serrated spine and extending backward a distance three times interorbital space; a very short fold on top of tail extending back of reflexed spine a distance equal to interorbital space; top of tail for remainder of its length roughened by minute spine-like tubercles; a median dorsal row of short but strong spines originating behind gill-cavity and reaching to base of serrated tail-spine; many small tubercles on either side of this row anteriorly; width of mouth contained two and one-half times in space between anterior gill-openings; margin of nasal flap with a short fringe; color uniform blackish above, pale below; tail without bands. The tail is shorter than in *Dasyatis bennetti* and the armature somewhat different. It is questionable whether this identification is correct and the species may be undescribed.

FIG. 2. *Dasyatis akajei* (Schlegel). (After Jordan and Evermann, Proc. U. S. N. M., Vol. 25, p. 319.)

14. **Dasyatis akajei** (Schlegel).
Formosa (Jordan & Evermann).

Family ELOPIDÆ.

15. **Elops hawaiiensis** Regan. (Plate LXVI, upper figure.)

Depth 6.8; head 4.2; snout a litte longer than eye, the transverse diameter of which is 3 in maxillary; interorbital width (measured on skull) a little over 5 in head; maxillary extending beyond eye, more than one-half length of head; lower jaw shutting inside upper (tip slightly projecting), so that the whole of the premaxillary band of teeth is exposed when the mouth is closed; length of gular plate two-thirds that of lower jaw; twenty-seven branchiostegals; thirteen gill-rakers on lower limb of anterior arch; ninety-seven scales in a longitudinal series from gill-opening to the base of the caudal; dorsal twenty-three, with nineteen branched rays; anal fifteen, with twelve branched rays; pectoral one-half width of pupil, more than one-half length of head, extending three-sevenths of the distance from its insertion to the front of the ventrals; origin of the ventrals slightly nearer the base of the caudal than the end of the snout; caudal peduncle scarcely compressed anteriorly, its width over the tip of the anal scarcely less than its depth; least depth of caudal peduncle $3\frac{1}{2}$ in head, least width 6.

One specimen thirty-six inches and one twelve inches long were received from Takao. The larger specimen seems to agree well with one thirty-four inches long recorded by Evermann and Seale (1906) from the Philippines, measurements of which have been furnished by Dr. Evermann. Specimens in the museum of Stanford University from Honolulu and Manila seem also to belong to this species, though none of these is over fourteen inches in length. In specimens of that size and under the body is notably less slender and the caudal peduncle much more compressed than in the adult specimen here recorded from Formosa.

This species is recorded by Jordan & Evermann from Suwata, Formosa, as *Elops machnata*, which is the species of the Red Sea.

Family MEGALOPIDÆ.

15. **Megalops cyprinoides** (Broussonet).
Giran, Formosa (Jordan & Evermann).

Family CHIROCENTRIDÆ.

16. **Chirocentrus dorab** (Forskål).
(Native name *Sai do*).
One specimen twenty-two inches and two sixteen inches long from Takao.

Family CHANIDÆ.

17. **Chanos chanos** (Forskål).

Giran, Taihoku, and Toii (Jordan & Evermann).

Family CLUPEIDÆ.

18. **Sardinella toli** (Cuvier & Valenciennes).

Five specimens three to four inches long from Takao. Kotosho (Jordan & Evermann). The genus *Sardinella* is identical with *Harengula* and probably also with *Kowala*. The Sardines and Pilchards should stand as *Amblygaster* Bleeker, a name earlier than that of *Sardinia* Poey.

19. **Amblygaster maculatum** (Richardson).

Giran (Jordan & Evermann).

20. **Amblygaster immaculatum** (Kishinouye).

Seven specimens, four and one-half inches long from Takao, Formosa.

Dorsal 16 or 17; anal 16; scales 44; head 3.6 in length without caudal, a pupil's width more than greatest depth of body; depth 4.3 in length; body compressed, greatest width nearly 2 in depth; eye 3 in head, equal to snout without adipose eyelid; lower jaw slightly projecting when mouth is closed; maxillary 2 in head, not quite reaching middle of eye; small teeth in front of lower jaw; vomer, tongue and palatines smooth; origin of dorsal nearer snout than base of caudal; ventrals inserted in front of middle of dorsal; gill-rakers fine, length two-thirds of eye; scales deciduous, posterior edges smooth or broadly sinuate, some with evident striæ.

Color silvery below, bluish black above; upper and lower jaw tipped with blackish; a narrow median frontal line of blackish from above pupil to even with nostrils.

This is probably identical with *Clupea immaculata* described by Kishinouye from the Riu Kiu Islands.

21. **Ilisha elongata** Bennett.

Formosa (Jordan & Evermann).

22. **Dussumieria elopsoides** (Bleeker).

Kotosho (Jordan & Evermann).

Family ENGRAULIDÆ.

23. **Anchovia hamiltoni** (Gray).

(Native name *Poe koe.*)

Four specimens three to four inches long from Takao.

24. **Anchovia indica** (Van Hasselt).
(Native name *Gang a hii; Jau a.*)
Three specimens four inches long from Takao.

25. **Anchovia koreana** (Kishinouye).
(Native name *Un na.*)
One specimen four inches long from Takao. Dorsal 12; anal 30; lower jaw very short.

Family DOROSOMIDÆ.

26. **Konosirus thrissa** (Osbeck) = *Dorosoma nasus* (Bloch).
(Native name *Beng pian.*)
Four specimens seven and one-half inches long from Takao.

Family SALMONIDÆ.

27. **Plecoglossus altivelis** Temminck & Schlegel.
Taihoku (Jordan & Evermann).

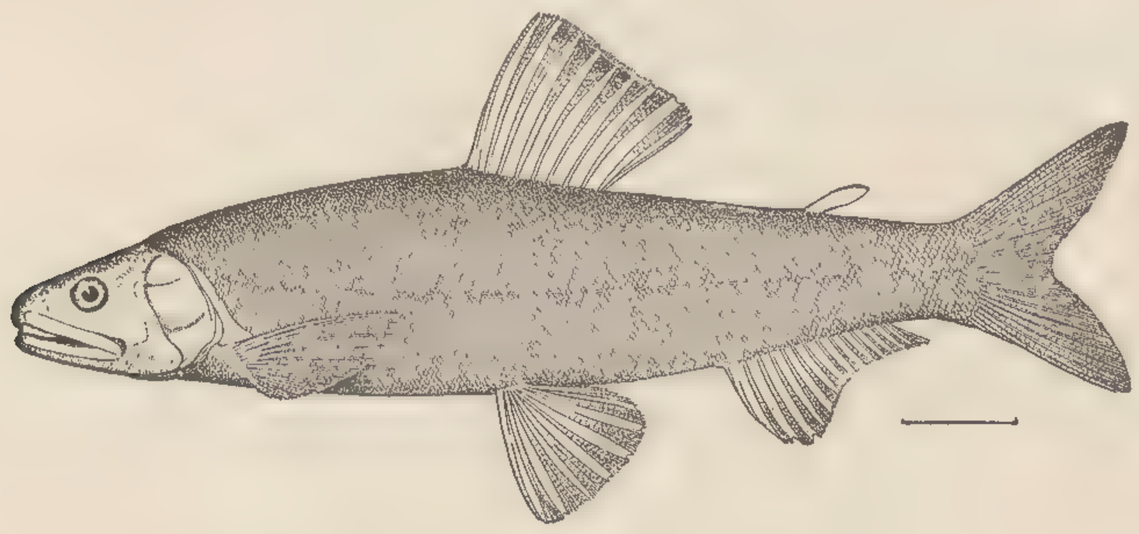


FIG. 3. *Plecoglossus altivelis* Tem. & Schl. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 328.)

Family SALANGIDÆ.

28. **Parasalanx acuticeps** (Regan).
Lake Candidius, Formosa (Regan).

Family SYNODONTIDÆ.

29. **Trachinocephalus myops** (Forster).
(Native name *Gau bu.*)
Seven specimens five to six and one-half inches long from Takao. We have not yet separated the Japanese *Trachinocephalus trachinus* from *T. myops* of the Atlantic.

30. **Saurida gracilis** (Quoy & Gaimard).

(Native name *Soa tngah.*)

Six specimens three to eight inches long from Takao.

31. **Saurida argyrophanes** (Richardson).

(Native name *Gau bu.*)

Three specimens twelve inches long from Takao. Adipose eyelid thick and broad, as much so as in the figure of *Saurida eso* of Jordan & Herre.

32. **Saurida tumbil** (Cuvier) ?

A single specimen from Takao, six and one-half inches long, is referred with doubt to this species. Scales 61; cross bands not evident on back; adipose eyelid narrow.

Family PLOTOSIDÆ.

33. **Plotosus anguillaris** (Bloch).

Five specimens from Takao, six to eight inches long. Giran (Jordan & Evermann).

Family SILURIDÆ.

34. **Parasilurus asotus** (Linnæus).

Taihoku (Jordan & Evermann).

FIG. 4. *Parasilurus asotus* (Linnæus). (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 320.)

35. **Tachysurus sinensis** Lacépède.

Suwata (Jordan & Evermann).

36. **Tachysurus falcarius** Richardson.

Suwata (Jordan & Evermann).

37. **Liobagrus formosanus** Regan.

Lake Candidius (Regan).

Family CLARIIDÆ.

38. **Clarias fuscus** (Lacépède).

(Native name *tan* or *taro sat*).

One specimen from Takao, seven inches long.

Taihoku (Jordan & Evermann).

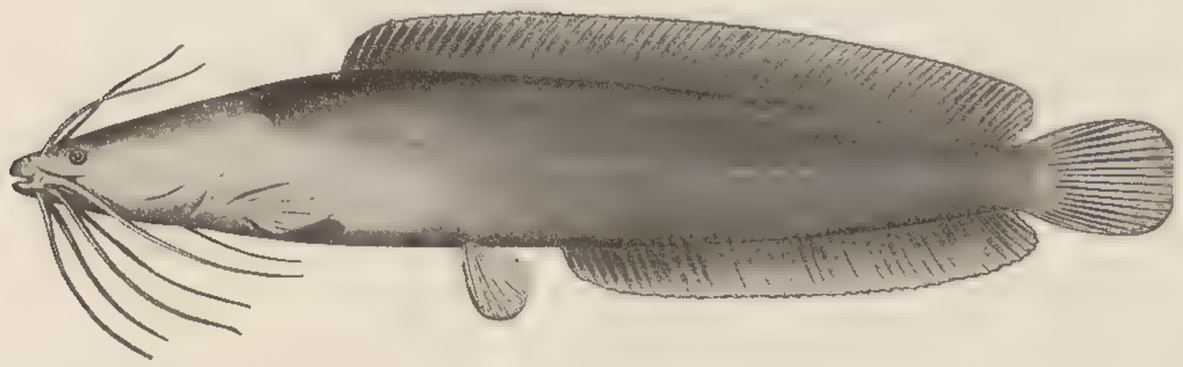


FIG. 5. *Clarias fuscus* (Lacépède). (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 321.)

Family COBITIDÆ.

39. **Misgurnus decemcirrosus** (Basilewsky).

Three specimens from Formosa, Tan Sin River at Taihoku (Jordan & Evermann). Scales 121; depth 6.7 in length; longest barbel 2 in head. This is a fish with a deeper, less pointed head, and paler color than *M. anguillicaudatus*.

Family CYPRINIDÆ.

40. **Carassius auratus** (Linnæus).

Four specimens from Takao.

41. **Cyprinus carpio** Linnæus.

Formosa (Jordan & Evermann).

42. **Gymnostomus labiatus** Regan.

Lake Candidius (Regan).

43. **Rohita decora** (Peters).

Formosa (Jordan & Evermann).

44. **Candidia** (gen. nov.) **barbata** (Regan) = *Opsariichthys barbatus* Regan.

From Lake Candidius (Regan).

This species, differing from *Opsariichthys*, by the presence of barbels, must be regarded as the type of a distinct genus, *Candidia*.

45. **Ctenopharyngodon idellus** (Cuvier & Valenciennes).

Taihoku (Jordan & Evermann).

46. **Hemibarbus barbus** (Temminck & Schlegel, Günther).

Formosa (Jordan & Evermann).

47. **Culter brevicauda** Günther.

Formosa (Günther, Jordan & Evermann).

48. **Cirrhina** sp.

Formosa (Jordan & Evermann).

49. **Pararasbora maltrechti** Regan.
Lake Candidius, Formosa (Regan).

50. **Zacco pachycephalus** (Günther).
Suwata, Taihoku (Jordan & Evermann).

51. **Zacco evolans** Jordan & Evermann.
Tan Sin River, Taihoku (Jordan & Evermann).

FIG. 6. *Zacco evolans* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 323.)

52. **Acheilognathus mesembrinum** Jordan & Evermann.
Kotosho (Jordan & Evermann).

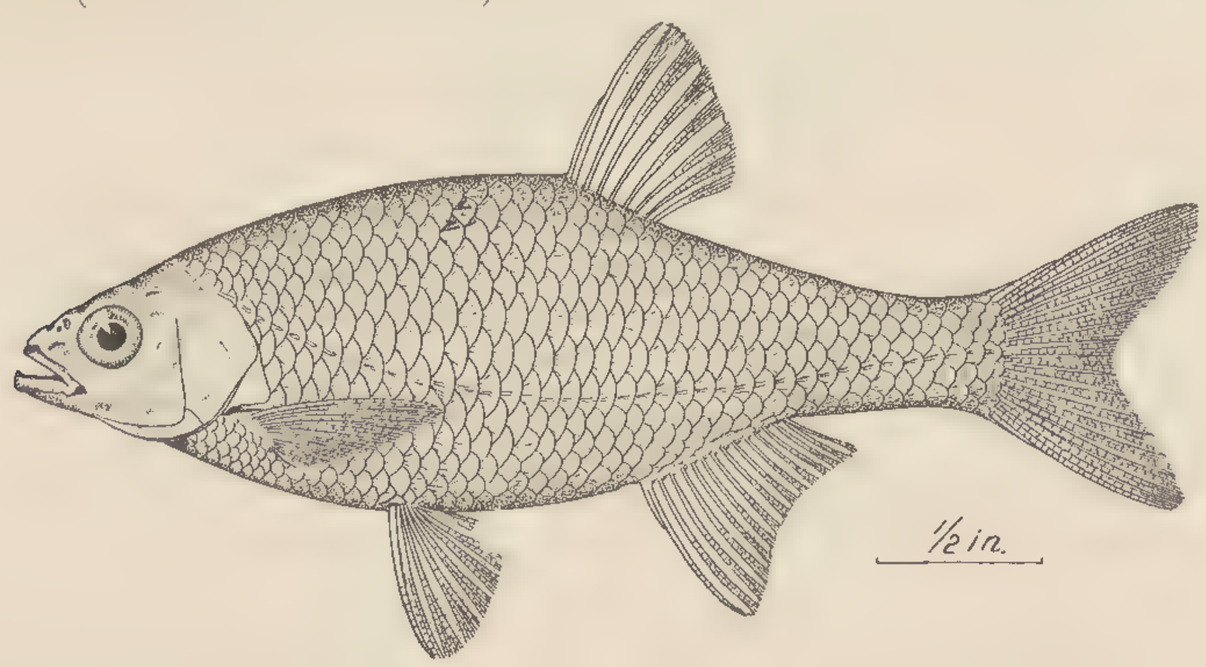


FIG. 7. *Acheilognathus mesembrinum* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 324.)

53. **Dillonia** sp.
Formosa (Jordan & Evermann).

Family MONOPTERIDÆ.

54. **Monopterus albus** Zuieuw.
Hokoto (Jordan & Evermann).

Family ANGUILLIDÆ.

55. **Anguilla sinensis** McClelland.
Seven specimens, thirteen to sixteen inches long, from Takao. Taihoku (Jordan & Evermann).

56. **Anguilla manilensis** (Bleeker).
Kotosho, Jordan & Evermann.

57. **Anguilla mauritiana** Bennett.
Kotosho, Jordan & Evermann.

58. **Anguilla remifera** Jordan & Evermann.
Hokoto (Jordan & Evermann).

FIG. 8. *Anguilla remifera* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 325.)

Family LEPTOCEPHALIDÆ.

59. **Leptocephalus anagoides** (Bleeker).
(Native name *Tsoan.*)
Eleven specimens from Takao six to eleven inches long. This species seems to differ clearly, though slightly, from *Leptocephalus* (*Congrellus*) *anago* (Schlegel) in the more anterior insertion of the dorsal (in front of base of pectoral), darker color about head, especially on under side, broader black margin on dorsal and anal, and reduction in size, or absence, of the white tip of the tail.

60. **Leptocephalus ectenurus** sp. nov. (Plate LXVI, lower figure.)
Head 1.25 to 1.3 in trunk; head and trunk 1.9 to 2.12 in total length; tail

tapering rapidly, becoming very slender toward tip, much as in *Uroconger lepturus;* head notably large, occipital region elevated; snout long, 1.5 times eye, 3.75 in head, projecting beyond lower jaw a distance equal to two-thirds of eye; eye 5.3 in head; anterior and posterior nostrils with low raised flaps; cleft of mouth reaching to middle of eye; teeth in jaws all pointed, closely set in broad bands in both jaws; vomerine patch subtriangular, rounded anteriorly; a few scattered, pointed teeth slightly longer than the rest in the front portion; the posterior (vomerine) teeth short and blunt; circular part of patch of teeth on vomer exposed when mouth is closed; tongue free; pectoral 3.3 in head; dorsal beginning over gill-opening, distinctly in front (one-half width of pupil) of pectoral; thirty-one pores before vent.

Color in spirits light olive brown, paler below; top and sides of head more heavily punctulated with dusky; dorsal and anal black edged, the whole of both fins tending to blackish on last third or half of tail; pectorals plain; tip of tail black.

Described from two excellent specimens eighteen and nineteen inches long from Takao.

This species seems to bridge the rather slight distinction heretofore made between *Leptocephalus* and *Congrellus*, having the long tail of the former and the anteriorly inserted dorsal of the latter.

We may note that *Myrophis* (*Gnathophis*) *heterognathus* (Bleeker) seems to be a young specimen of *Leptocephalus nystromi* Jordan and Fowler, both species being described from Nagasaki. The species should stand as *Leptocephalus heterognathus.*

Family OPHICHTHYIDÆ.

61. **Ophichthus evermanni** sp. nov. (Plate LXVII, upper figure.)

Two specimens from Takao, seventeen and twenty-one inches long, seem to agree fairly well with the "variety" *Ophichthus cephalozona* recorded by Dr. Günther from Japan (Catalog of Fishes in the British Museum, Vol. VIII, p. 70), having the body very distinctly marked with numerous blotches resembling cross-bands. The nuchal band is scarcely less distinct than in the figure by Dr. Bleeker. The dorsal of one specimen shows no distinct white edge, while in the other (nineteen inches long) the white margin shows plainly. In both specimens the dorsal partakes more or less of the mottled coloration of the body. The pectoral is $3\frac{1}{2}$ or 4 in head; the dorsal begins in front of the posterior fourth of the reflexed pectoral.

This species is recorded as *Ophichthus cephalozona* from Hokoto, by Jordan & Evermann.

62. **Pisoödonophis boro** (Hamilton Buchanan).

Toii (Jordan & Evermann).

Family MURÆNIDÆ.

63. **Echidna polyzona** (Richardson).

One specimen eighteen and one-half inches long from Takao.

64. **Gymnothorax reticularis** Bloch.

Five specimens ten to fourteen inches long from Takao.

65. **Gymnothorax pescadoris** Jordan & Evermann.

Pescadores Islands (Hokoto) (Jordan & Evermann).

FIG. 9. *Gymnothorax pescadoris* J & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 326.)

66. **Gymnothorax fimbriatus** (Bennett).

(*Murænophis stellatus* Lacépède?; *Gymnothorax isingleenoides* Bleeker.)

One specimen from Takao, twelve and one-half inches long, agreeing in all respects with Bleeker's description and figure (of young) of *G. isingleenoides*. The specimen agrees very well also with examples from Samoa, recorded by Jordan & Seale as *G. stellatus* (Lacépède) and with a single young specimen from Sumatra received from Mr. H. W. Fowler. It may be that the name *stellatus* should stand in place of *fimbriatus*. *Muræna bullata* Richardson, figured by Bleeker, seems to be distinct.

67. **Gymnothorax flavomarginatus** (Rüppell).

One specimen from Takao twenty-two inches long.

68. **Gymnothorax pseudothyrsoideus** (Bleeker). (Perhaps not of Day.)

A large specimen two feet in length from Takao, appears to agree in all essential respects with Bleeker's figure and description. The dorsal begins half way between the gill-opening and the back of the orbit; the ground color is rather dark brown, finely reticulated, or marbled everywhere with lighter, and is scarcely paler on the chin and the belly than on the upper parts; there is no black about the gill-opening, and no light border to the fins except at the tip of the tail. The species is near

Gymnothorax philippinus Jordan & Seale, but seems to have a heavier body, less pointed tail, and darker chin and belly. The markings on the sides of the tail are obscured in the specimen.

69. **Gymnothorax melanospilos** (Bleeker). (Plate LXVII, lower figure.)

Head 6.9 in total length, 2.5 in trunk; head and trunk equal in length to tail; depth 2 in head; snout 5.75 in head, much compressed, its width in front of eyes hardly more than one-third width of head; eye small, 12 in head, 2 in snout.

Body rather slender, the tail tapering but the tip rounded rather than pointed; mouth large, the eye midway between its angle and tip of snout; teeth in single series; two depressible canines in upper jaw; gill-opening a little longer than eye; dorsal inserted half way between gill-opening and eye, its height apparently a little less than half the depth of the body; anal low.

Ground color in spirits light purplish brown, considerably paler on chin and fore part of belly; body and fins everywhere covered with roundish or elongate (when double) black spots, as a rule a little larger than eye, and when confluent or double oftenest arranged longitudinally; there are evident on the tail three more or less distinct longitudinal rows of the larger spots, and a row of smaller ones along the base of the anal; the spots on the trunk and head are not in distinct rows, though about four or five rows might be surmised as the basis of the pattern; the spots on chin, cheeks, and snout are distinct, but smaller and more irregular in form than those on the hinder part of the head and on the tail and body; on the neck underneath the gill-opening are about five narrow blackish longitudinal streaks, coinciding with cuticular creases; the dorsal has a basal and a marginal row of spots like those of the body, while the anal has one row of such spots; the edge of both dorsal and anal is pale between the black spots, but there is not a continuous pale edge, except at tip. (Dr. Günther, who had Bleeker's type, says *G. melanospilos* has fins with a narrow whitish edge.)

This species seems scarcely different from *Gymnothorax pescadoris* Jordan & Evermann, except in coloration (spots on head and tail larger). The width of the snout is not stated in the original description of that species. The very much compressed snout of our specimen (agreeing with Günther's statement about *G. melanospilos*) is very striking.

70. **Gymnothorax leucostigma** sp. nov. (Plate LXVIII.)

Head 6.6 in length, 2.05 in trunk, 3.6 in tail; tail about $\frac{1}{2}$ head's length longer than head and trunk; depth 1.7 in head; snout 5.5; eye 11.5.

Body rather heavy and short, tail pointed; occipital region elevated, the de-

scent steep to eye; snout compressed laterally to scarcely more than the width of the interorbital space, which is 3 in width of head; mouth large, the eye being midway between its angle and tip of snout; teeth in single series in jaws; no depressible canines or other teeth on vomer; gill-opening about diameter of eye; dorsal inserted in front of gill-opening one-third distance from it to front of eye; height of dorsal more than one-third depth of body; height of anal about equal to eye.

Ground color reddish brown; head, body, tail, and fins covered with large roundish pale spots, usually larger but sometimes smaller than eye; the spots are plainer and in three to four fairly definite rows on tail, and there are four to five indefinite rows on body; the spots on sides and top of head are numerous, but much smaller than the large ones on body; chin, breast, and belly apparently without spots and not much paler than the upper ground color; some blackish about gill-opening, in the thoracic creases, and at angle of mouth; dorsal with two rows of pale spots, anal with one row; margin of dorsal blackish between pale spots.

One specimen 31 inches long from Takao.

71. **Evenchelys macrurus** (Bleeker).

One specimen forty-three inches long from Takao; Kotosho (Jordan & Evermann).

Family BELONIDÆ.

72. **Tylosurus caudimaculatus** (Cuvier).

One specimen twelve inches long from Takao.

73. **Tylosurus coromandelicus** (Van Hasselt).

(Native name *O lan.*)

Two specimens, one twenty inches, and the other sixteen inches long, from Takao.

74. **Tylosurus schismatorhynchus** (Bleeker).

(Native name *O lan.*)

One specimen twenty inches long from Takao.

75. **Tylosurus leiurus** (Bleeker).

Formosa (Jordan & Evermann).

76. **Tylosurus melanostigma** (Cuvier & Valenciennes).

Formosa (Jordan & Evermann).

Family HEMIRAMPHIDÆ.

77. **Hemiramphus far** (Forskål).

Two specimens, respectively ten and twelve inches long, from Takao. Formosa (Jordan & Evermann).

78. **Hemiramphus melanurus** Cuvier & Valenciennes.
Fifteen specimens three to five inches long from Takao.

79. **Hemiramphus georgii** Cuvier & Valenciennes.
Formosa (Jordan & Evermann).

80. **Euleptorhamphus longirostris** (Cuvier).
Formosa (Jordan & Evermann).

Family EXOCŒTIDÆ.

81. **Cypsilurus spilonotopterus** (Bleeker).
Formosa (Jordan & Evermann).

Family FISTULARIIDÆ.

82. **Fistularia petimba** (Lacépède).
Four specimens five to fifteen inches long from Takao. Formosa (Jordan & Evermann).

Family MUGILIDÆ.

83. **Mugil cœur** Forskål.
Keerun; Taihoku (Jordan & Evermann).

84. **Liza troscheli** (Bleeker).
One specimen six inches long from Takao. Hokoto (Jordan & Evermann).

Family SPHYRÆNIDÆ.

85. **Sphyræna jello** Cuvier & Valenciennes.
(Native name *Soh ah.*)
Two specimens ten inches long from Takao. Formosa (Jordan & Evermann).

86. **Sphyræna langsar** Bleeker.
Two specimens twelve inches long from Takao.

87. **Sphyræna japonica** Temminck & Schlegel.
Formosa (Jordan & Evermann).

88. **Sphyræna forsteri** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

Family ATHERINIDÆ.

89. **Atherina bleekeri** Günther.
Four specimens three inches long from Takao.

Family POLYNEMIDÆ.

90. **Polydactylus plebeius** (Broussonet).
Four specimens three to ten inches long from Takao. Scales 63 to 65; pectoral filaments 5.

91. **Polydactylus zophomus** Jordan & McGregor.
Kotosho (Jordan & Evermann) (as *P. plebeius*).

92. **Eleutheronema tetradactylum** (Shaw). (*Polydactylus rhadinus* Jordan & Evermann.)

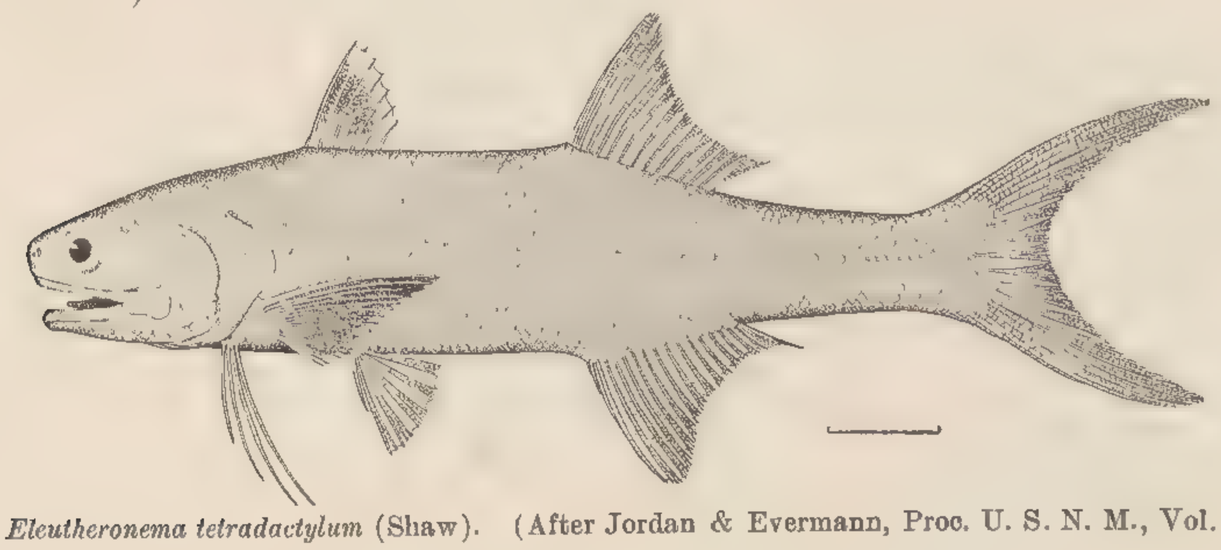


FIG. 10. *Eleutheronema tetradactylum* (Shaw). (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25. p.351.)

Two specimens, respectively ten and twelve inches long, from Takao. Described from Formosa by Jordan & Evermann as *Polydactylus rhadinus*. Our specimens agree fairly well with the published figure of Jordan & Evermann.

The genus *Eleutheronema* Bleeker may perhaps be retained as defined by the absence of the air-bladder. This is present in *Polydactylus*.

Family HOLOCENTRIDÆ.

93. **Ostichthys japonicus** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

Family SCOMBRIDÆ.

94. **Scomber japonicus** Houttuyn.
Formosa (Jordan & Evermann).

95. **Rastrelliger kanagurta** (Russell).
Formosa (Jordan & Evermann).

96. **Euthynnus alleteratus** (Rafinesque).
Three specimens ten inches long from Takao. Formosa (Jordan & Evermann).

The genus *Euthynnus* Lütken should apparently be separated from *Gymnosarda* (*nuda*). The latter has the corselet scaleless, covered by wrinkled skin (Rüppell).

97. **Scomberomorus commersoni** (Lacépède).
(Native name *To to.*)
One specimen twenty-one inches long from Takao.

98. **Scomberomorus guttatus** (Bloch & Schneider).
(Native name *Be ka.*)

One specimen twenty inches long from Takao.

99. **Scomberomorus kuhlii** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

Family CARANGIDÆ.

100. **Scomberoides sancti-petri** (Cuvier & Valenciennes).
(Native name *Shi chang ah.*)
Three specimens from Takao, four to eight inches long.

101. **Scomberoides tol** (Cuvier & Valenciennes).
Five specimens from Takao, ten inches long. Giran (Jordan & Evermann, as *S. orientalis*).

102. **Megalaspis cordyla** (Linnæus).
(Native name *Thi gha.*)
Two specimens from Takao, fourteen inches long. Formosa (Jordan & Evermann).

103. **Decapterus muroadsi** (Temminck & Schlegel).
Formosa (Jordan & Evermann).

104. **Decapterus macrosomus** (Bleeker).
Formosa (Jordan & Evermann).

105. **Trachurops crumenophthalma** (Bloch).
(Native name *Ba lang.*)
One specimen from Takao, nine inches long. Formosa; Giran (Jordan & Evermann, as *T. forva*).

106. **Caranx leptolepis** Cuvier & Valenciennes.
Keerun (Jordan & Evermann).

107. **Caranx malabaricus** (Schneider).
Keerun (Jordan Evermann).

108. **Caranx jarra** Cuvier & Valenciennes.
Keerun (Jordan & Evermann).

109. **Caranx affinis** Rüppell.
One specimen from Takao, eleven inches long.

110. **Caranx djeddaba** (Forskål).
One specimen from Takao, eleven and one-half inches long.

111. **Caranx sexfasciatus** (Quoy & Gaimard).
(Native name *Amba Koyo* = "red eye.")
Two specimens from Takao, one eight and one-half inches, and another fourteen inches long.

112. **Caranx forsteri** Cuvier & Valenciennes.
Keerun (Jordan & Evermann, as *C. sexfasciatus*).

113. **Caranx ignobilis** (Forskål).
(Native name *Go yan.*)
One specimen from Takao, six inches long.

114. **Caranx speciosus** (Forskål).
One specimen from Takao, twelve inches long.

115. **Caranx plumbeus** (Quoy & Gaimard).
(Native name *Go yen.*)
Three specimens from Takao, eight to ten inches long.

116. **Caranx rastrosus** Jordan & Snyder. (Plate LI.)
(*Caranx plumbeus* Jordan & Seale, Cavite, P. I.)
(Native name *Go yen.*)
One example, thirteen and one-half inches long, the type, from Takao.

117. **Caranx formosanus** Jordan & Snyder. (Plate LII.)
(Native name *Go yan.*)
One specimen, the type, eleven and one-half inches in length, from Takao.
Formosa (Jordan & Evermann, as *C. armatus*).

118. **Ulua richardsoni** Jordan & Snyder. (Plate LIII.)
One large specimen eighteen inches long, type of the species, and one cotype, eight inches long, from Takao.

119. **Apolectus niger** (Bloch).
One specimen from Takao.

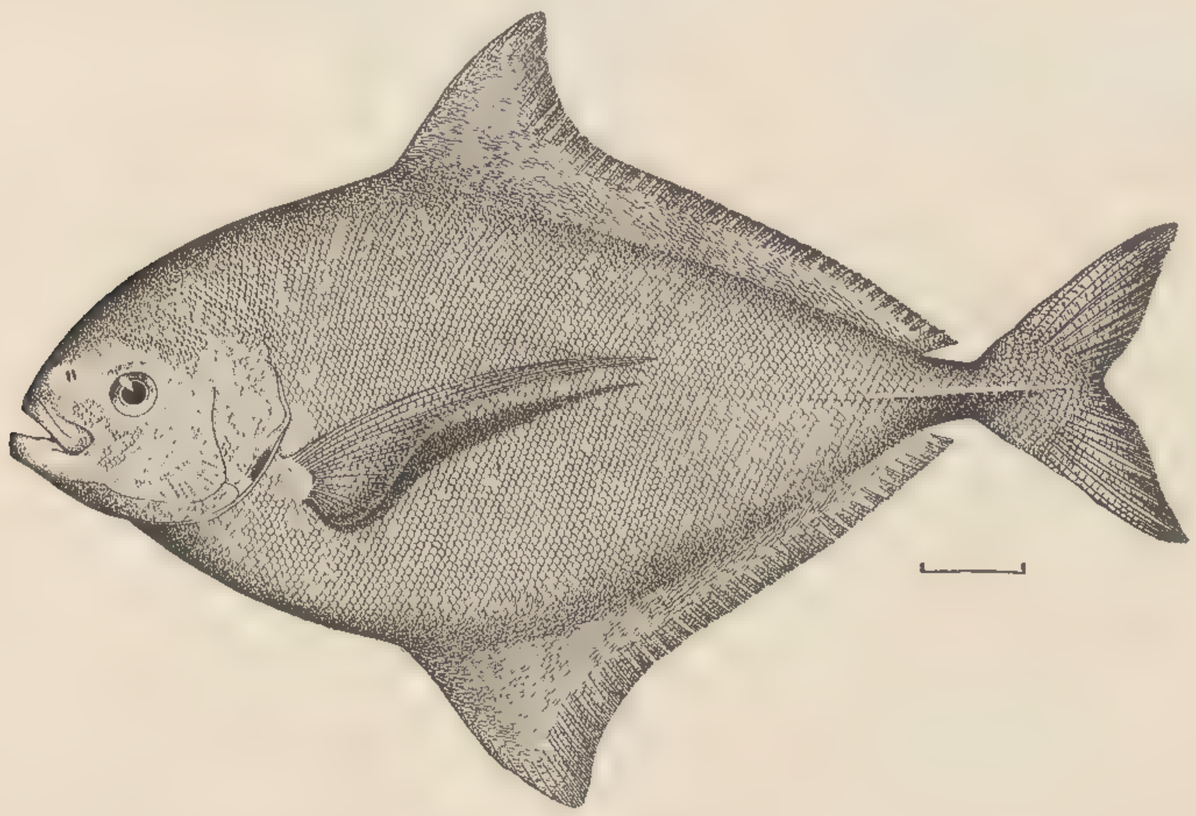


FIG. 11. *Apolectus niger* (Bloch). (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 339.)

120. **Trachinotus bailloni** (Lacépède).

Three examples from Takao, three to thirteen inches long.

121. **Trachinotus russelli** Cuvier & Valenciennes.

One specimen from Takao, fifteen inches long.

122. **Trachinotus ovatus** (Linnæus).

One large specimen, twenty-seven inches long, from Takao.

123. **Alectis major** (Cuvier & Valenciennes).

Two fine specimens, seven and ten inches long, from Takao. This is identical with *Zeus gallus* Bloch, not of Linnæus, and with *Scyris indica* Rüppell. It seems to be distinct from *Alectis ciliaris.*

Formosa (Jordan & Evermann, as *A. ciliaris*).

Family MENIDÆ.

124. **Mene maculata** (Bloch).

Five specimens from Takao, four inches long.

Family RACHYCENTRIDÆ.

125. **Rachycentron canadum** (Linnæus).

Three specimens, sixteen to twenty-four inches long, from Takao.

Family TRICHIURIDÆ.

126. **Trichiurus haumela** (Forskål).

Three specimens from Takao, Formosa, eighteen inches to three feet long. Scales 134 or 135; eye in snout 2.5 in smaller, 2.7 in larger specimen; whip of tail less slender and elongate than in specimens of *T. japonicus* from China.

127. **Trichiurus japonicus** Temminck & Schlegel.

Hokoto (Jordan & Evermann).

Family LEIOGNATHIDÆ.

128. **Leigonathus caballus** (Cuvier & Valenciennes).

(Native name *Go yan.*)

Five specimens from Takao, five to nine inches long.

129. **Leiognathus splendens** (Cuvier).

Three specimens from Takao, one to two inches long.

Formosa (Jordan & Evermann).

130. **Leiognathus rivulatum** (Temminck & Schlegel).

Twelve specimens from Takao, two to three inches long.

131. **Leiognathus edentulum** (Bloch).

Formosa (Jordan & Evermann). (Probably the same as *L. caballus.*)

132. **Gazza æquulæformis** (Rüppell).

Kotosho (Jordan & Evermann).

133. **Equula ruconia** (Hamilton-Buchanan).

Three young specimens from Takao, one to one and one-half inches long. Somewhat slimmer than *E. ruconia* of larger size from the Philippines.

Family STROMATEIDÆ.

134. **Psenopsis anomala** (Temminck & Schlegel).

One specimen three inches long from Takao.

Family PEMPHERIDÆ.

135. **Pempheris nyctereutes** Jordan & Evermann.

Hokoto (Jordan & Evermann).

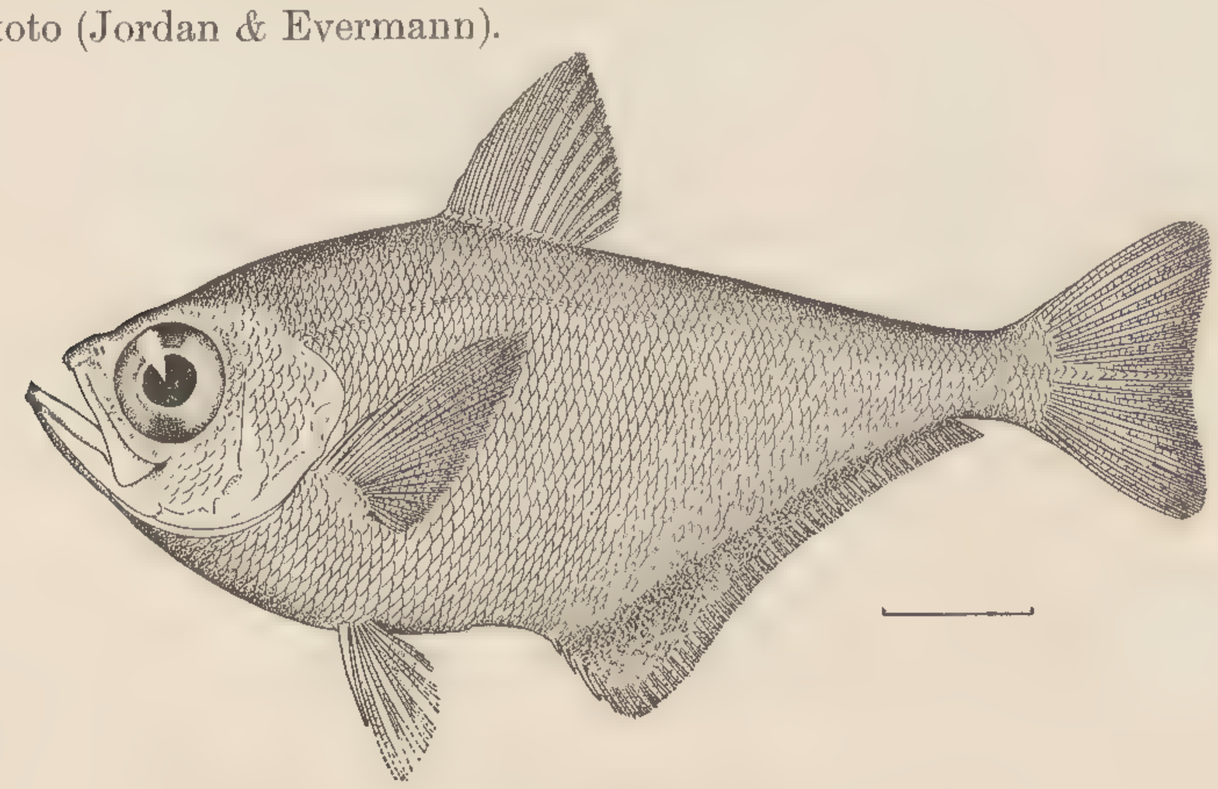


FIG. 12. *Pempheris nyctereutes* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 340.)

Family APOGONICHTHYIDÆ.

136. **Amia quadrifasciata** (Cuvier & Valenciennes).

Four specimens, two and one half inches long, from Takao. *Amia elizabethæ* Jordan & Seale (Proceedings Davenport Academy of Sciences, Vol. X, p. 9, Pl. IV, 1905) is very close to this species, but the lower stripe is fainter and the body deeper.

137. **Apogonichthys fo** (Jordan & Seale).

Two specimens, two inches long, from Takao.

138. **Archamia macropteroides** (Bleeker).

Six specimens, two to two and three quarters of an inch long, from Takao.

139. **Archamia notata** (Day).[1] (Plate LXIX.)

[1] Not *Apogon notatus* Jordan & Snyder = *Sparus notatus* Houttuyn which is a valid *Amia*.

Head 2.5 in length; depth 2.75 to 2.9; eye 3 in head, 8.5 to 9 in length to base caudal; snout 4.7 to 4.9 in head; interorbital 4.2; dorsal VI–I, 9; anal II, 16 or 17; scales 3–25–5.

Body noticeably more elongate and thinner than in *Archamia macropterus*[2] (Bleeker); depth of caudal peduncle 2.3 in head; profile straight to a point over front of eye, the tip of the snout a very little upturned; mouth large, upturned; maxillary 2.2 in head; maxillary extending to nearly under middle of eye; upper lip on level with middle of eye; tip of lower jaw slightly projecting when mouth is closed; minute villiform teeth in jaws and on vomer and palatines; no canines; 16 gill-rakers on lower limb of outer arch, longer than the corresponding filaments, the longest about 2 in eye; preopercle finely denticulated about angle on both hinder and lower margin; operculum with a thin flat point, even with middle of eye, and a little above it a second less prominent point; scales ctenoid; lateral line apparently complete (some scales missing in all specimens); cheeks scaled; origin of spinous dorsal half-way between axil of soft dorsal and front of eye; longest dorsal spine 2.7 in head, first dorsal spine $\frac{2}{3}$ second; origin of anal a little in front of that of soft dorsal; ventrals 1.8 in head, their origin slightly in front of base of pectorals; pectorals 1.4; caudal weakly emarginate.

Color in spirits light straw, rather sparsely and faintly punctulated above on head and body; lower parts of sides and belly nearly plain; a small but very distinct blotch at base of caudal, its diameter less than one-half that of pupil; tip of lower jaw dusky; dorsals, caudal, and anal tinged with dusky; no fin with dark tip or edge; no spot on shoulder.

Described from six specimens from Takao, two to two and one-half inches long.

This species seems to be well distinguished from *Archamia macropteroides* by its slenderer form, smaller eye, different coloration, fewer punctulations tending to form no pattern, and the prominent but very small caudal spot. The first dorsal spine is little shorter than the second, which is also the case in *Archamia bleekeri* Günther (= *Apogon macropterus* Bleeker, not Kuhl & Van Hasselt). In *Archamia macropteroides* the first spine is scarcely more than half the length of the second. In *Archamia bleekeri* there is a distinct black blotch on the shoulder, as well as at base of caudal. In *Archamia macropteroides* the caudal spot is much less distinct, and the shoulder spot indistinct or absent. *Archamia fucata* (Cantor) has a smaller mouth and most of the other nominal species have fewer rays in the anal fin.

[2] The specimen from Samoa called *Archamia lineolata* by Jordan & Seale should probably stand as *Archamia macropteroides*. *Archamia lineolata* from the Red Sea with fourteen soft rays in the anal and with twelve dark cross streaks must be different and also distinct from the present species.

Family KUHLIIDÆ.

140. **Kuhlia marginata** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

Family SERRANIDÆ.

141. **Psammoperca waigiensis** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

142. **Lateolabrax japonicus** (Cuvier & Valenciennes).
Keerun; Formosa (Jordan & Evermann).

143. **Epinephelus tauvina** (Forskål).
(Native name *Loh wah.*)
Nine specimens from Takao, three to eight inches long. Dorsal XI, fourteen or fifteen; teeth in sides of lower jaw in two rows.
Keerun (Jordan & Evermann).

144. **Epinephelus moara** (Temminck & Schlegel).
A single large specimen, twenty-three inches long, from Takao.

145. **Epinephelus chlorostigma** (Cuvier & Valenciennes).
One large specimen, eighteen inches long, from Takao. It does not appear to differ from Japanese examples.
Keerun (Jordan & Evermann).

146. **Epinephelus awoara** (Temminck & Schlegel).
Two specimens, one eight and one half inches, the other fifteen inches long, from Takao. Mr. Sauter states that the color in life is "light brown, with the under parts suffused with yellow; fins grey, with yellow borders." The specimens in spirits show five indistinct broad cross-bands, and the large one has traces of pale spots on the head and the lower anterior part of the sides. A full description, with figure is reserved for publication in a paper in preparation on the serranoid fishes of Japan.

147. **Epinephelus fuscoguttatus** (Forskål).
Formosa (Jordan & Evermann).

148. **Epinephelus epistictus** (Temminck & Schlegel).
Giran; Formosa (Jordan & Evermann).

149. **Epinephelus diacanthus** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

150. **Epinephelus hœdti** (Bleeker).
Formosa (Jordan & Evermann).

151. **Promicrops lanceolata** (Bloch).

Formosa (Jordan & Evermann).

Family LUTIANIDÆ.

152. **Lutianus argentimaculatus** (Forskål).

(Native name *Ang tsoh.*)

One specimen from Takao, ten and one-half inches long. Keerun (Jordan & Evermann).

153. **Lutianus fuscescens** (Cuvier & Valenciennes) = *Mesoprion hoteen* Richardson.

Five specimens, three to five inches long, from Takao. Specimens from Keerun, called *Lutianus fulviflamma* by Jordan & Evermann, probably belong to this species.

154. **Lutianus quinquelineatus** (Bloch)?

Four small specimens, two inches long, from Takao.

155. **Lutianus fulviflamma** (Forskål).

(Native names *Chan tsi ah; Chiochi.*)

Three specimens from Takao, two and one-half to four inches long, agreeing perfectly with the ones obtained by Mr. McGregor at Cuyo, Philippine Islands, and recorded by Jordan & Richardson as *Lutianus russelli.*

156. **Lutianus annularis** (Cuvier & Valenciennes).

Formosa (Jordan & Evermann).

157. **Lutianus kasmira** (Forskål).

One specimen, three inches long, from Takao.

158. **Lutianus vitta** (Quoy & Gaimard).

(Native name *Si Kong.*)

Two specimens, eight inches long, from Takao. Keerun (Jordan & Evermann).

159. **Lutianus lineolatus** (Rüppell).

A specimen from Takao, seven and one-half inches long, is referred with some doubt to this species. It bears a general resemblance to *L. vitta,* but is well distinguished from that species by its slenderer body, larger eye, and longer pectoral. Depth 3.1; eye 3.2; pectoral nearly equal to head; a faint dusky stripe, less than width of pupil, from middle of eye to base of caudal, and three or four narrower and fainter ones below it; the posterior nostril is notably small, being more roundish and less slit-like than in most species of *Lutianus.*

160. **Lutianus rivulatus** (Cuvier & Valenciennes).

Two specimens, two and one-half to three inches long, from Takao.

161. **Lutianus erythropterus** Bloch.

(Native name *Hai ling.*)

Four specimens, four to eight inches long, from Takao.

162. **Glaucosoma burgeri** Richardson.

Two large specimens from Takao.

Keerun (Jordan & Evermann).

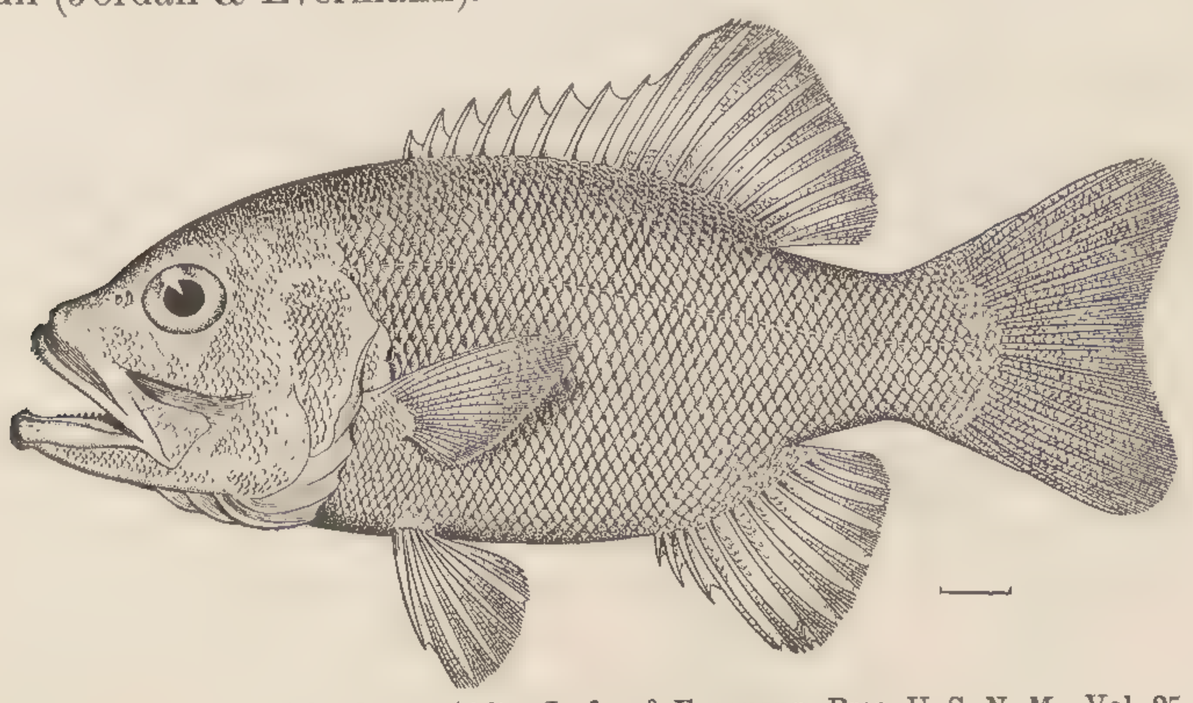


FIG. 13. *Glaucosoma burgeri* Richardson. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 342.)

163. **Platyinius sparus** (Temminck & Schlegel).

Formosa (Jordan & Evermann).

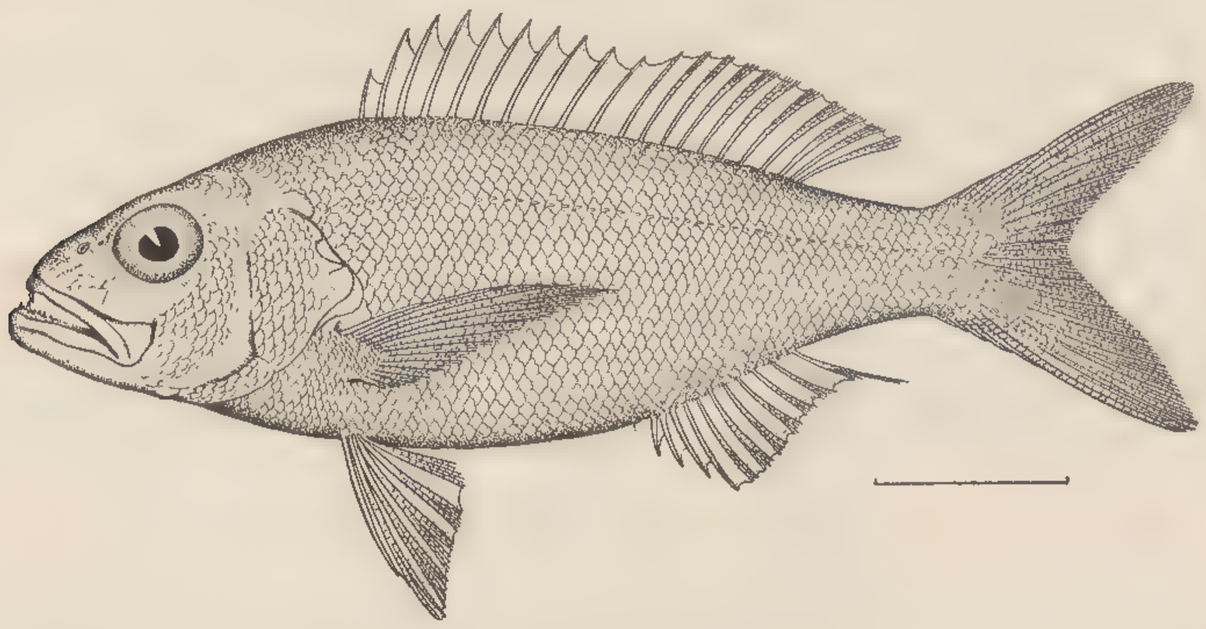


FIG. 14. *Platyinius sparus* (Tem. & Schleg.). (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 344.)

164. **Dentex hypselosomus** Bleeker. (For figure see p. 186.)

(Native name *Ga lah.*)

Three specimens, nine inches long, from Takao.

Formosa (Jordan & Evermann.)

165. **Nemipterus ovenii** (Bleeker).

(Native name *Ang hii.*)

Five specimens from Takao, seven to eight and one half inches long.

166. **Nemipterus virgatus** (Houttuyn).

Keerun (Jordan & Evermann).

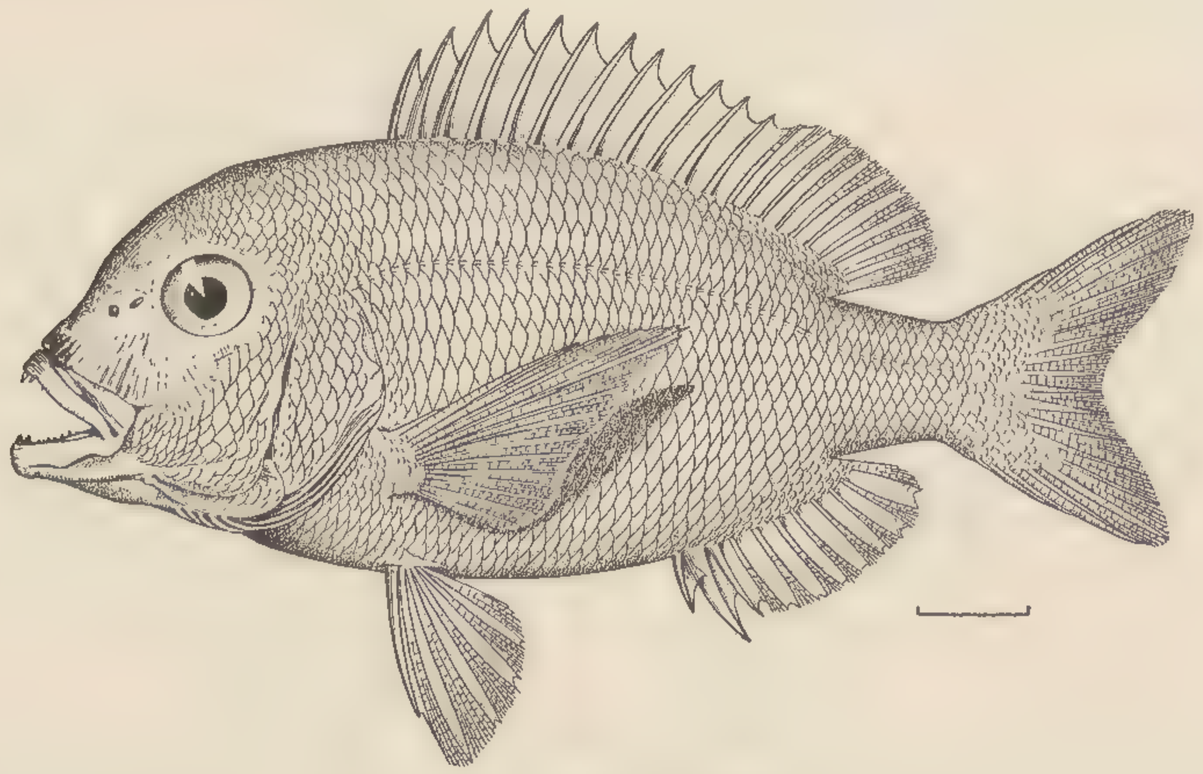


FIG. 15. *Dentex hypselosomus* Bleeker. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 345.)

167. **Nemipterus matsubaræ** Jordan & Evermann.

Giran (Jordan & Evermann).

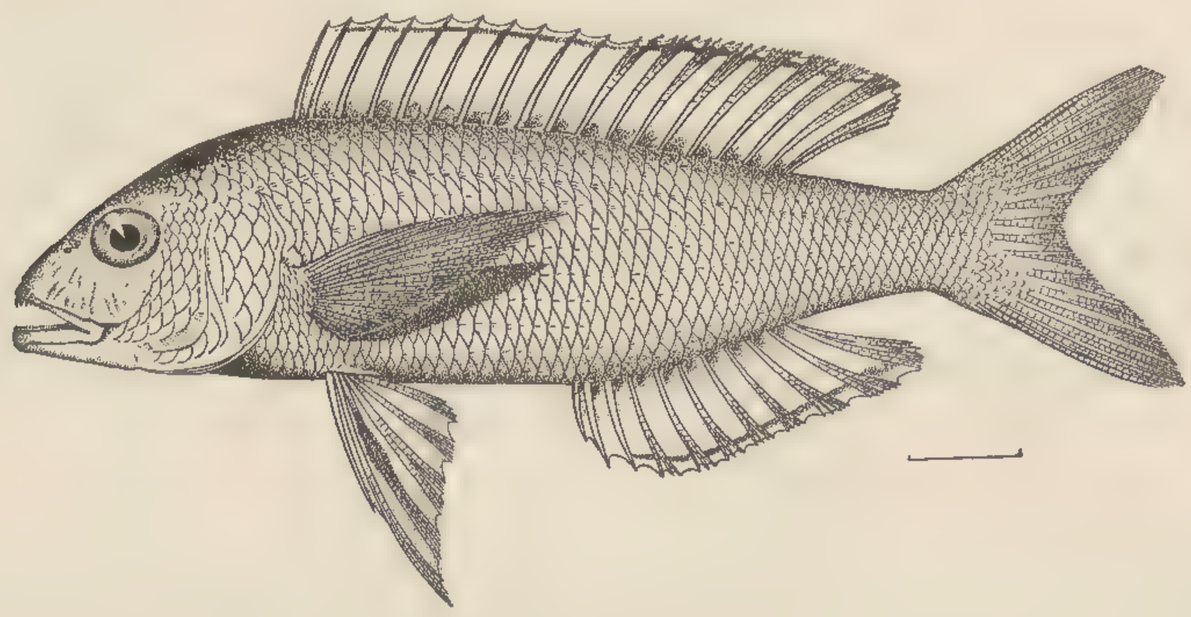


FIG. 16. *Nemipterus matsubaræ* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 347.)

168. **Nemipterus japonicus** (Bloch) = *Synagris japonicus* of Day, not of Günther.

A specimen, eleven and one half inches long, from Takao, agrees fairly well with Day's description and figure, but the serrature of the preopercular edge is very faint, and the dorsal rays are only eight in number. Day examined Bloch's type in Berlin.

Family HÆMULIDÆ.

169. **Terapon theraps** (Cuvier & Valenciennes).
Keerun (Jordan & Evermann).

170. **Terapon cancellatus** (Cuvier & Valenciennes).
Kotosho (Jordan & Evermann).

171. **Terapon quadrilineatus** (Bloch).
Two specimens, one and one half to three inches long, from Takao.
Giran; Keerun (Jordan & Evermann).

172. **Terapon jarbua** (Forskål).
Two specimens, eight inches long, from Takao.
Formosa (Jordan & Evermann).

173. **Terapon sexlineatus** (Quoy & Gaimard).
One specimen, five inches long, from Takao.

174. **Plectorhynchus ocyurus** Jordan & Evermann.
Formosa (Jordan & Evermann).

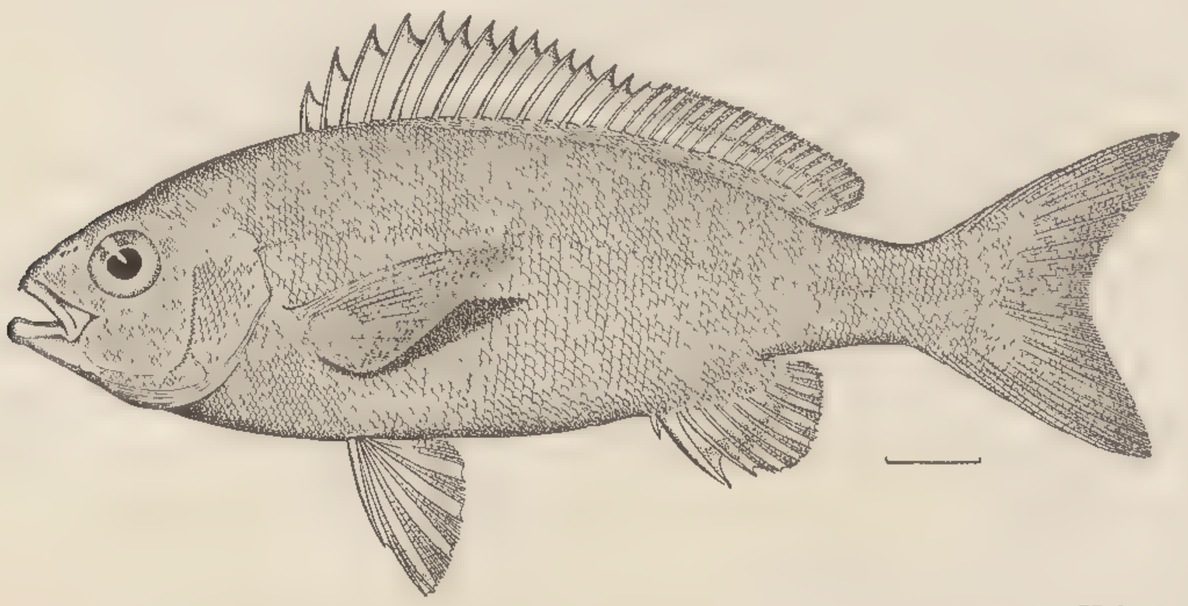


FIG. 17. *Plectorhynchus ocyurus* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 348.)

175. **Plectorhynchus radjaban** (Lacépède).
Formosa (Jordan & Evermann).

176. **Plectorhynchus pœcilopterus** (Cuvier & Valenciennes).
Keerun; Giran (Jordan & Evermann).

177. **Pomadasis hasta** (Bloch).
One specimen, eleven inches long, from Takao.
Keerun (Jordan & Evermann).

178. **Pomadasis maculatus** (Bloch).
Three specimens, eight inches long, from Takao.
Keerun (Jordan & Evermann).

179. **Scolopsis vosmeri** (Bloch).

One specimen, four and one-half inches long, from Takao.

Keerun (Jordan & Evermann).

180. **Scolopsis monogramma** (Kuhl & Van Hasselt).

Giran; Keerun (Jordan & Evermann).

181. **Scolopsis eriomma** sp. nov. (Plate LXX.)

Head 3.4; depth 2.6; width 2.4 in depth; eye 2.9; snout 1.3 in eye; maxillary 2.75 in head; interorbital space equal to eye; dorsal X, 9; anal III, 7; scales 3–48–12. Body oblong, compressed, dorsal and ventral outlines about equally arched; head short, muzzle rather rounded than pointed; mouth moderate, oblique, lower jaw slightly projecting; back of maxillary under front of pupil; teeth in jaws fine, villiform, in broad bands, a few of the outer ones slightly enlarged as very weak canines; vomer, palatines, and tongue without teeth; eye very large, its diameter one-third greater than length of snout; posterior limb of preopercle very finely but distinctly serrate; opercle with a short but strong and sharp spine; depth of infraorbital over back of maxillary less than one-third of eye, its lower hinder edge with several small serratures, the upper one of which is strongest; nostrils moderate, subequal; gill-rakers eleven on lower limb of outer arch, their length about half that of the corresponding filaments; the larger rakers terminating in a flattish, disk-like expansion, which is fringed. Scales very large, ctenoid; cheeks with three rows behind eye, four below it; lateral line complete, arched, about parallel with back; pores thirty-five. Dorsal fins continuous, the spines strong and stiff, the longest (fourth or fifth) 2.25 in head; origin of dorsal over base of pectoral; insertion of anal slightly in front of second soft ray of dorsal; caudal moderately forked, the lobes subequal; pectoral nearly as long as head, pointed, reaching past tips of ventrals and nearly to vent; ventrals 1.4 in head.

Color in alcohol light straw, tinged with pinkish along middle of side; belly whitish; no black markings on body or fins. (The color in life was probably reddish.)

Described from three specimens from Takao, in excellent condition, eight to nine inches long. Vernacular name said by Mr. Sauter to be *Dai hii* or *Hai tai*.

182. **Cæsio chrysozona** (Kuhl & Van Hasselt).

Keerun (Jordan & Evermann).

183. **Cæsio bile** Cuvier & Valenciennes.

Keerun (Jordan & Evermann).

184. **Anoplus banjos** (Bleeker).

Formosa (Jordan & Evermann).

Family SPARIDÆ.

185. **Lethrinus amboinensis** Bleeker.

(Native name *Leng tsian.*)

Six specimens, three to six inches long, from Takao.

Depth 2.6; head 2.8; snout $1\frac{1}{2}$ times eye; teeth conical. The cross-bars on body show plainly in the specimens, and the ventrals are barred, not plain, or with diffuse dusky, as in many species of *Lethrinus.* The specimens from the Lung collection recorded by Jordan & Seale as *Lethrinus amboinensis* have the ventrals plain, and are probably a different species.

186. **Lethrinus leutjanus** (Bloch).

Giran (Jordan & Evermann).

187. **Lethrinus richardsoni** Günther.

Formosa (Jordan & Evermann).

188. **Lethrinus insulindicus** Bleeker.

We provisionally refer a specimen eleven inches long from Takao to this species. The depth is 2.6; nose $2\frac{1}{2}$ times eye. There are traces of dark cross-bars on the upper portion of the sides and a suggestion of a dusky blotch under the lateral line forward; ventrals plain. A color note by Mr. Sauter states that in life the "general color was light greenish-brown, whitish beneath; iris yellow; opercular flap and base of pectoral crimson; caudal dusky, suffused with red; hind part of dorsal red; membranes of anal reddish at border." This description agrees well with the coloring in Bleeker's plate.

189. **Pagrus major** (Temminck & Schlegel).

(Native name *Ga la hii.*)

One specimen, eleven inches long, from Takao.

Formosa (Jordan & Evermann).

190. **Pagrus cardinalis** (Temminck & Schlegel).

Formosa (Jordan & Evermann).

191. **Argyrops longifilis** (Cuvier & Valenciennes).

(Native name *Poa'n.*)

Two specimens from Takao, seven and one-half inches long.

Kotosho (Jordan & Evermann).

192. **Sparus berda** Forskål.

Formosa (Jordan & Evermann).

193. **Sparus latus** Houttuyn.

Giran (Jordan & Evermann).

194. **Sparus longispinus** (Temminck & Schlegel).

(Native name *Ang ke.*)

A fine specimen from Takao, twelve inches long, agrees in all essential respects with the original description and figure by Temminck & Schlegel of the type from Japan.

Family KYPHOSIDÆ.

195. **Girella mezina** Jordan & Starks.

One example, eleven and one-half inches long, in good color, was received from Takao. It is very dark in color, the pale cross-bar shown in the original type being entirely obliterated. Apparently this marking, like the white spot on the back of the related California species, *Girella nigricans*, is a character of youth. The *Crenidens leoninus* of Richardson from Canton after a figure of Reeves may be this species, or it may be the Japanese species called *Crenidens melanichthys* by Richardson and *Girella leonina* by Jordan & Starks (Proc. U. S. Nat. Mus., 1907, p. 497). In view of this uncertainty, until we know which species occur at Canton, we may use the name *Girella melanichthys* for this species, which is the *Melanichthys* of Temminck & Schlegel. There are thus three species of *Girella* in the waters of southern Japan and Formosa. These are, *Girella punctata* Gray, *Girella melanichthys* Richardson (= *Melanichthys* Schlegel = *Girella leonina* Jordan & Starks, perhaps not *Crenidens leoninus* Richardson) and *Girella mezina* Jordan & Starks (perhaps = *Crenidens leoninus* Richardson). Temminck & Schlegel describe and figure the opercle in *Melanichthys* as scaled throughout, which is not the case. The figure shows the more oblong form and general profile of the fish we call here *Girella melanichthys*.

The type of *Girella punctata* came also from Canton. The description of Dr. Günther (Cat. I, p. 427) evidently includes *Girella melanichthys* as well as *Girella punctata*.

Family GERRIDÆ.

196. **Xystæma punctatum** (Cuvier & Valenciennes).

Three specimens from Takao, four to seven inches long. Of fifteen specimens examined from the Philippines and Formosa none had more than seven anal rays. This is the *Xystæma punctatum* of Jordan & Seale and probably also the original *Gerres punctatus* of Cuvier & Valenciennes.

Kotosho (Jordan & Evermann).

197. **Xystæma abbreviatum** (Bleeker).

(Native name *O-ke*.)

One specimen from Takao, four inches long. The anal has eight rays, though two young specimens from Cavite have only seven. These were not distinguished from *X. punctatum* by Jordan & Seale. This is, however, a shorter, deeper-bodied

fish than *X. punctatum* (*filamentosum*), has thicker and less flexible, dorsals pines, and has a dark spot on each scale above the lateral line, and four or five less distinct rows of such spots below it.

Family SCIÆNIDÆ.

198. **Pseudotolithus brunneolus** sp. nov. (Plate LXXI.)

(Native name *Ga bang he.*)

Head 3.40; depth 4; eye 4 in head; nose 4; maxillary 2.2; interorbital 4; dorsal X, 30–31; anal II, 7–8; scales 8–56–13. Body moderately elongate, compressed; head bluntly pointed; mouth large, oblique; jaws equal; maxillary reaching slightly past the middle of the orbit; interorbital space slightly convex, nearly flat; opercle with a weak flat spine; upper and lower limb of preopercle each with a few small and weak denticles; gill-rakers on lower limb of outer arch twelve, counting rudiments, the longest equal in length to the corresponding filaments, less than one-half eye; teeth of upper jaw in two series, the outer consisting of a single row, strong, recurved, and canine-like; the inner villiform teeth presenting the appearance of a band in the posterior half of the jaw, but forming a single or nearly single row anteriorly; sides of lower jaw with canine-like teeth in a single row; some smaller teeth behind the canines at the symphysis. Origin of dorsal slightly behind that of pectorals; spinous and soft dorsals connected by a low membrane; third dorsal spine longest, 2.6 in head; anal spines weak, the second spine half the length of the longest rays; origin of anal under middle of soft dorsal, its base 4.7 in head; ventrals 1.5 in head; pectorals 1.2; caudal rhomboidal, 1.4 in head. Entire body and head scaled, except maxillary and lower jaw; lateral line complete, extending to end of caudal, the pores branched, 54 to 56 in number to base of caudal.

Color in spirits brownish above; paler (silvery), more or less densely punctulated with dusky on belly, breast, and lower parts of head and under jaws; a large diffuse dark blotch on opercle; spinous dorsal dusky, darkest on outer two-thirds; soft dorsal dusky, somewhat darker along margin; anterior part of anal brown-specked; posterior half of pectorals dusky; ventrals plain.

Described from three specimens, eight inches long, from Takao. We refer this species to the genus *Pseudotolithus* Bleeker, as a provisional matter. It is not clear that this genus differs from *Pseudosciæna* and it has much in common with *Odontorcion* and with *Corvula*.

199. **Corvula argentata** Houttuyn.

Formosa (Jordan & Evermann).

Family SILLAGINIDÆ.

200. **Sillago sihama** (Forskål).

Eight specimens from Takao, three to six inches long.

Formosa (Jordan & Evermann).

201. **Sillago æolus** Jordan & Evermann.

Keerun (Jordan & Evermann).

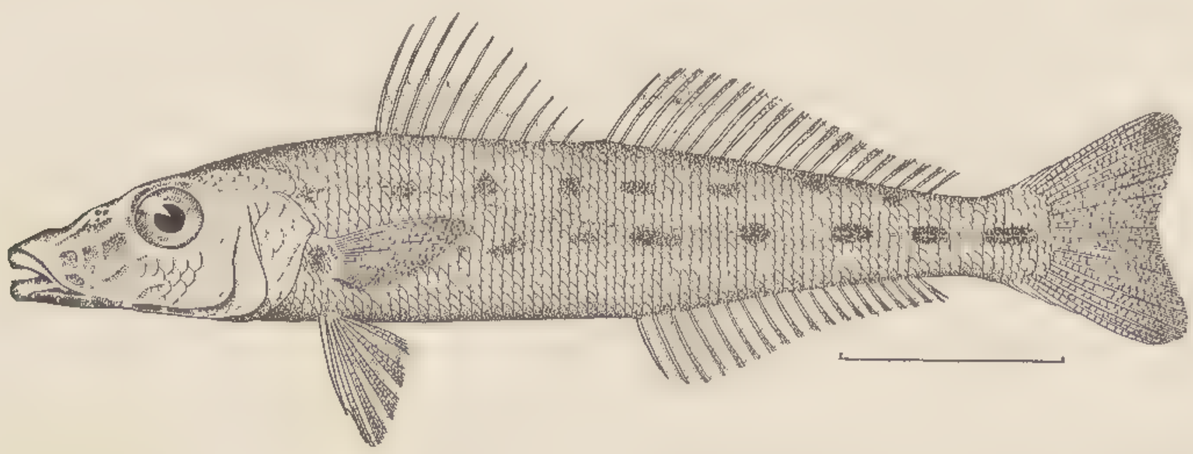


FIG. 18. *Sillago æolus* J. & E. (After Jordan & Evermann, Proc. U. S. N. M , Vol. 25, p. 360.)

Family PENTACEROTIDÆ.[1]

202. **Histiopterus typus** Temminck & Schlegel.

One specimen, Takao, twelve inches long.

Family PRIACANTHIDÆ.

203. **Priacanthus tayenus** Richardson.

(Native name *Giam kong.*)

Three specimens, ten inches long, from Takao, two males and one female. The female lacks the dorsal and upper caudal filament and the conspicuous black spots on the inside of the pectoral.

Family LATILIDÆ.

204. **Latilus japonicus** (Houttuyn).

Three specimens from Takao, ten to thirteen inches long.

Giran (Jordan & Evermann).

Family MULLIDÆ.

205. **Upeneus indicus** (Shaw).

(Native name *Hai tai.*)

[1] The name *Pentaceros* Cuvier & Valenciennes is apparently not preoccupied, as recently supposed by Jordan, Proc. U. S. M., XXXII, 1907, p. 238. The first use of the name *Pentaceros* for a starfish by Schultze, 1760, is non-binomial, according to Dr. Walter K. Fisher.

Eight specimens from Takao, three to ten inches long.
Keerun; Giran (Jordan & Evermann).

206. **Upeneus ischyrus** Snyder.
One large specimen from Takao, ten inches long.

207. **Upeneus cyclostomus** Lacépède.
(*Upeneus luteus* Cuvier & Valenciennes.)
Keerun (Jordan & Evermann).

208. **Upeneoides bensasi** (Temminck & Schlegel).
Three young specimens from Takao, three inches in length.
Keerun; Kotosho (Jordan & Evermann).

209. **Upeneoides tragulus** (Richardson).
(Native name *Hoe sin.*)
Seven specimens from Takao, four to ten inches long.
Giran; Keerun; Hokoto (Jordan & Evermann).

210. **Upeneoides vittatus** (Forskål).
Keerun (Jordan & Evermann).

Family OPHICEPHALIDÆ.

211. **Ophicephalus tadianus** Jordan & Evermann.
(Native name *Lochii.*)

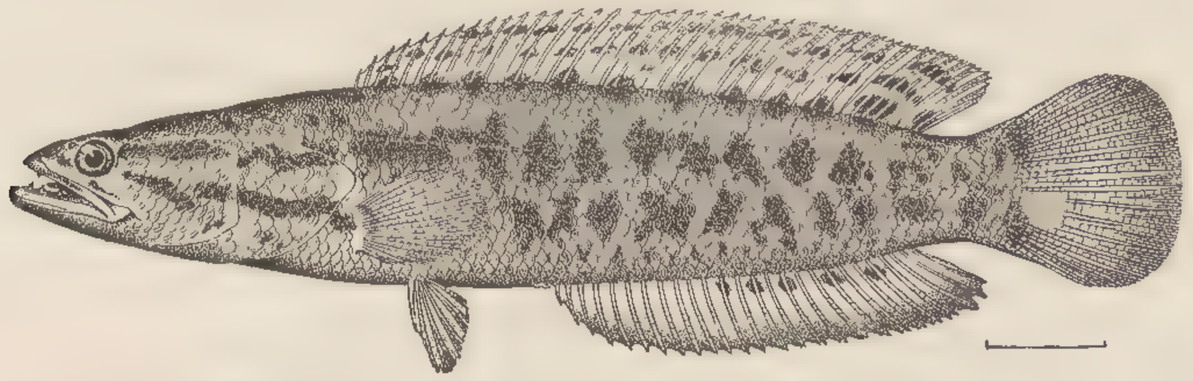


FIG. 19. *Ophicephalus tadianus* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 331.)

Eight large specimens, eight to fifteen inches long, from Takao. This species is allied to *O. polylepis* from Sumatra, as noted by Dr. Steindachner, but has a much larger mouth.

212. **Ophicephalus maculatus** Lacépède.
Giran (Jordan & Evermann).

213. **Channa formosana** Jordan & Evermann.
Suwata (Jordan & Evermann).

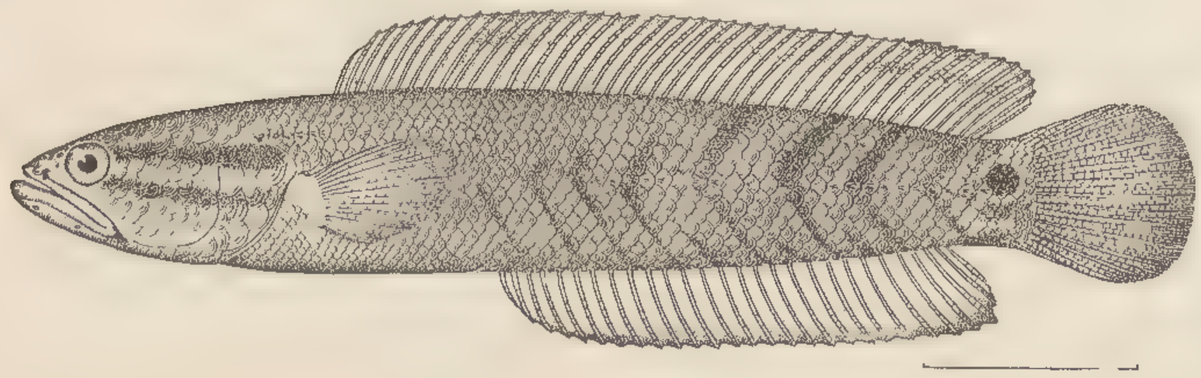


FIG 20. *Channa formosana* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 332.)

Family CHEILODACTYLIDÆ.

214. **Goniistius zonatus** (Cuvier & Valenciennes).
One specimen from Takao, twelve inches long.

Family SCORPÆNIDÆ.

215. **Sebastapistes tristis** (Klunzinger).
(Native name *Ho hii.*)
Seven small specimens from Takao, two and one-half inches long.

Family PLATYCEPHALIDÆ.

216. **Platycephalus indicus** (Gmelin).
One specimen from Takao, fourteen inches long.
217. **Thysanophrys scaber** (Linnæus).
Takao, one specimen five inches long.
218. **Thysanophrys japonicus** (Tilesius).
(? *Silurus inermis* Houttuyn.)
(Native name *Gu bo.*)
One specimen from Takao, seven inches long.

Family POMACENTRIDÆ.

219. **Abudefduf saxatilis** (Linnæus).
Formosa (Jordan & Evermann).
220. **Abudefduf sordidus** (Forskål).
Kotosho (Jordan & Evermann).

Family LABRIDÆ.

221. **Choirodon azurio** (Jordan & Snyder).
Keerun (Jordan & Evermann).

222. **Choirodon nyctemblema** (Jordan & Evermann).
Formosa (Jordan & Evermann).

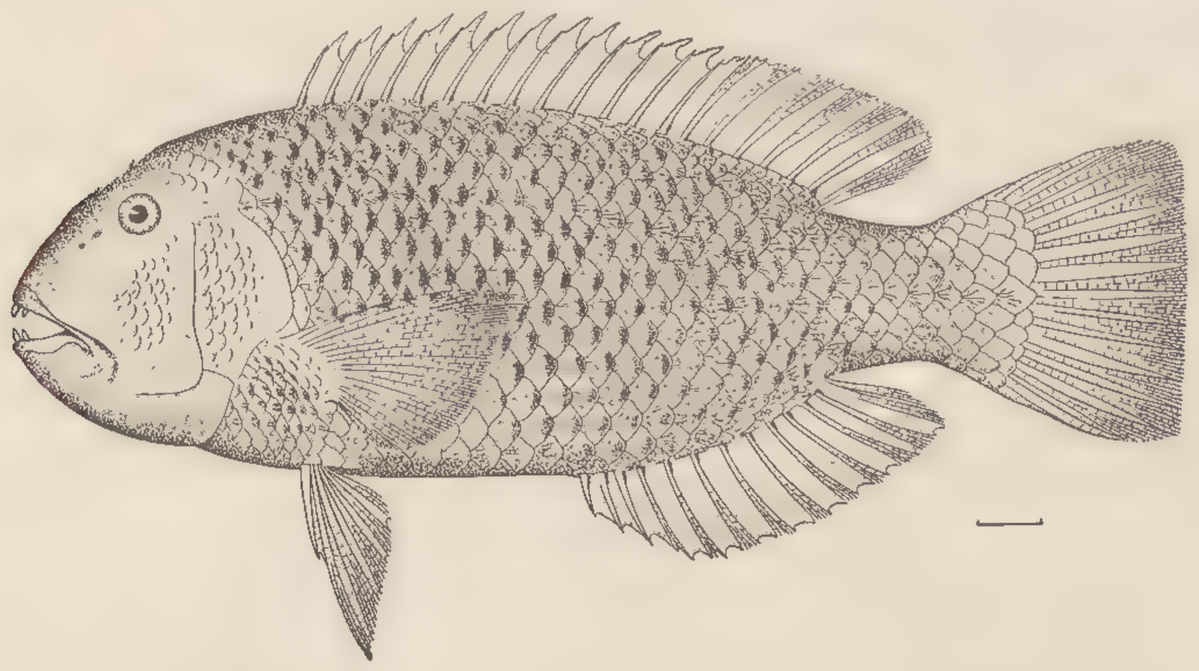


FIG. 21. *Choirodon nyctemblema* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 353.)

223. **Duymæria flagellifera** (Cuvier & Valenciennes).
Keerun (Jordan & Evermann).

224. **Anampses cæruleopunctatus** (Rüppell).
Formosa (Jordan & Evermann).

225. **Halichœres dussumieri** (Cuvier & Valenciennes) = *Halichœres nigrescens* Bleeker.
One specimen, Takao, three and one-half inches long.

226. **Hemipteronotus verrens** Jordan & Evermann.
Keerun (Jordan & Evermann).

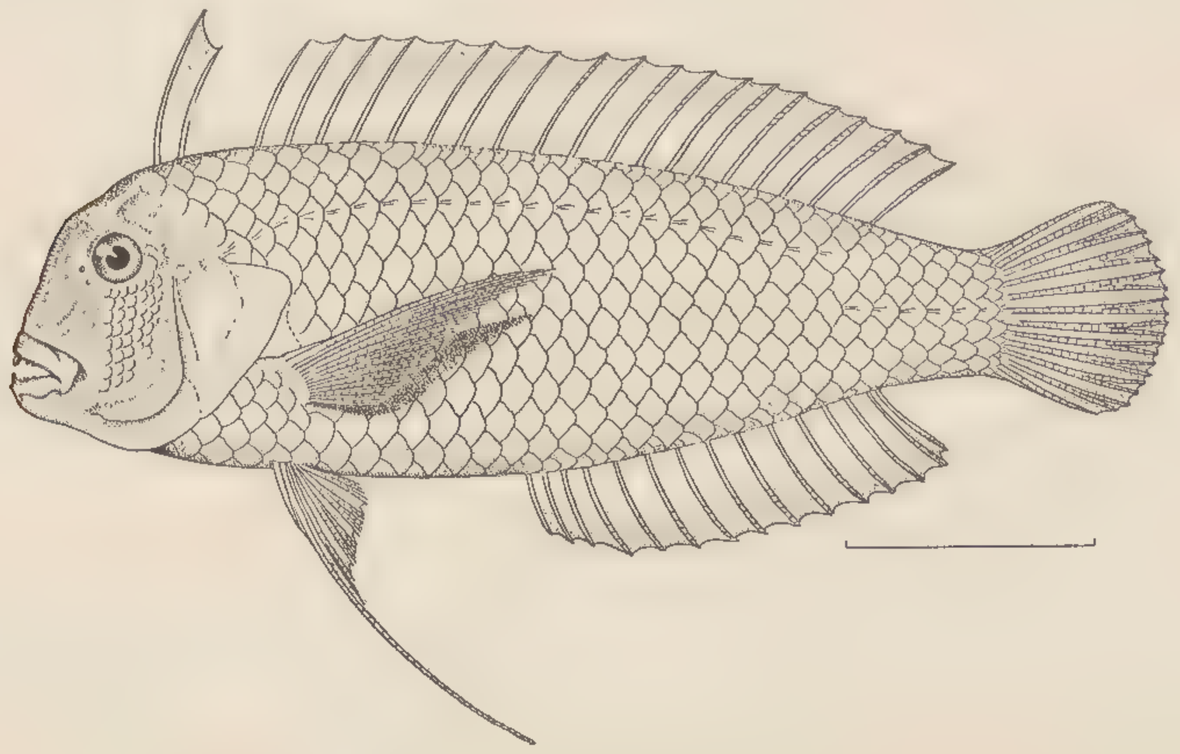


FIG. 22. *Hemipteronotus verrens* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 355.)

227. **Hemipteronotus pentadactylus** (Linnæus).

Nine specimens from Takao, five to six inches long.

228. **Hemipteronotus evides** sp. nov. (Plate LXXII.)

Head 3.25 in length; depth 2.6; eye 4.7 in head; snout 3; interorbital equal to eye; dorsal II–VII, 12; anal III, 12; scales 3–28–8. Body short, deep, much compressed, the greatest width $3\frac{2}{3}$ in greatest depth; head short and deep, the anterior profile nearly vertical; a depression over eye; eye high, nearly half of length of head above angle of mouth; mouth rather small, nearly horizontal, maxillary not reaching front of eye, 3 in head; teeth in jaws small, sharp, close set in a single row; two outwardly-directed recurved canines at front of each jaw. Scales thin; cheeks with smaller scales, in four or five rows; rest of head naked; lateral line high, continuous to near end of dorsal, where it breaks, to be continued on the third scale row below. Dorsal inserted over back of eye, the first two spines separated from the others by a deep notch, but not detached; length of second spine 2.4 in head; origin of anal under second ray of soft dorsal; caudal rounded; pectoral 1.3 in head, its free margin nearly straight; ventral with outer ray produced, reaching past front of anal.

Color in spirits dull greenish-olive; under posterior third of spinous dorsal an obliquish blotch of black surrounded by pale, the black covering most of three scales; dorsals and caudal with many small pale specks on a dusky ground; anal obliquely barred with dusky; ventrals plain; pectorals dusky.

Described from two specimens from Takao, four and five inches long.

229. **Cheilio inermis** (Forskål).

Three examples from Takao, seven inches long.

Formosa (Jordan & Evermann).

Family SCARICHTHYIDÆ.

230. **Scarichthys auritus** (Kuhl & Van Hasselt).

One specimen from Takao, seven inches long.

231. **Calotomus waigiensis** (Quoy & Gaimard).

(*Callyodon spinidens* Cuvier & Valenciennes.)

Four specimens from Takao, three and one-half to four inches long.

232. **Callyodon dussumieri** (Cuvier & Valenciennes). (Plate LXXIII.)

(Native name *Eng kochu.*)

A fine specimen twelve inches long from Takao, agreeing with Bleeker's figure and description of *Pseudoscarus dussumieri*, but with the right canine rather small and the left wanting. Valenciennes states that *Scarus dussumieri* has no canines at the angle of the jaws, but the description is based merely on a drawing.

233. **Callyodon lacerta** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

Family SCATOPHAGIDÆ.

234. **Scatophagus argus** (Gmelin).
One specimen from Takao, seven inches long.
Suwata and Giran (Jordan & Evermann).

Family EPHIPPIDÆ.

235. **Ephippus orbis** (Bloch).
Three specimens from Takao, six inches long.
Formosa (Jordan & Evermann).

The genus *Ephippus* of Cuvier includes *argus* and *orbis*, the former in the text, the latter in a footnote. The first restriction of the genus, that of Cuvier & Valenciennes, makes *orbis* the type of *Ephippus*. We have therefore so regarded it, in spite of the fact that it was not named in the text of the account of *Ephippus*, but only in a footnote. This view may be open to question.

Family PLATACIDÆ.

236. **Platax teira** (Forskål).
One specimen from Takao.
Formosa (Jordan & Evermann).

Family CHÆTODONTIDÆ.

237. **Chætodon reticulatus** Cuvier & Valenciennes.
Formosa (Jordan & Evermann).

238. **Chætodon lineolatus** (Cuvier & Valenciennes).
Pescadores Islands (Jordan & Evermann).

239. **Chætodon lunula** Lacépède.
Kotosho (Jordan & Evermann).

240. **Chætodon citrinellus** Cuvier & Valenciennes.
Kotosho (Jordan & Evermann).

241. **Microcanthus strigatus** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

Family HEPATIDÆ.

242. **Hepatus triostegus** (Linnæus).
Kotosho (Jordan & Evermann).

243. **Hepatus dussumieri** (Cuvier & Valenciennes).
Formosa (Jordan & Evermann).

244. **Hepatus bipunctatus** (Günther).
Kotosho (Jordan & Evermann).

245. **Hepatus olivaceus** (Bloch & Schneider).
Formosa (Jordan & Evermann).

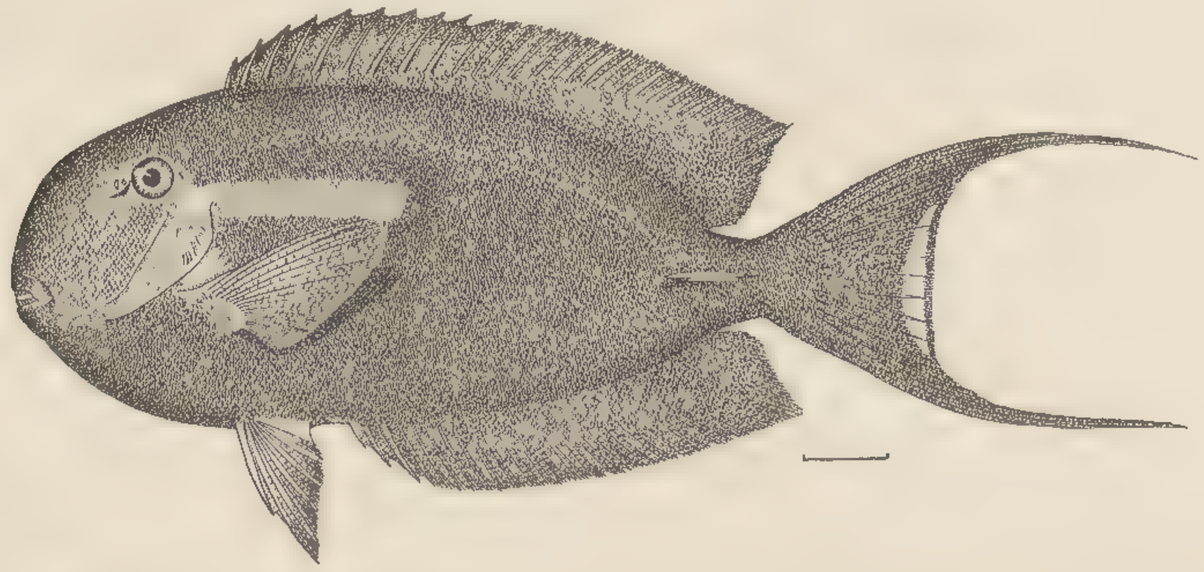


FIG. 23. *Hepatus olivaceus* (Bl. & Schneid.). (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 358.)

Family SIGANIDÆ.

246. **Siganus virgatus** (Cuvier & Valenciennes).
(Native name *Trau toh.*)
Two specimens from Takao, three inches long.

247. **Siganus vermiculatus** (Kuhl & Van Hasselt).
Suwata (Jordan & Evermann).

248. **Siganus fuscescens** (Houttuyn).
Three specimens, three to eight inches long, from Takao.
Keerun (Jordan & Evermann).

249. **Siganus guttatus** (Bloch).
(Native name *Niu e.*)
One example, eight inches long, from Takao. Specimens from southern Negros, P. I., recorded by Jordan & Seale as *Siganus lineatus* belong to this species. Others called *Siganus lineatus* from the Philippines belong to the next species, whatever that may prove to be.

250. **Siganus lineatus** (Cuvier & Valenciennes)?
(Native name *Niu e.*)
Two small specimens, three inches long, from Takao, are referred with considerable doubt to this species. They are apparently identical with specimens from

Manila and Cuyo, P. I., called *Siganus lineatus* by Jordan & Seale and Jordan & Richardson. (Bull. U. S. Bur. Fish., XXVI, 35, 1907, and XXVII, 271, 1908). A field note on the Cuyo specimen mentions a "large golden-yellow spot at back of dorsal," as in *Siganus lineatus*, which does not show in spirits. The preserved specimens all show some small dark spots about the caudal peduncle and on caudal, dorsal, and anal. None of them show the linear dark markings on the body figured by Cuvier & Valenciennes. Only a thorough comparison of many specimens, with perhaps an examination of original types, can show what names these and other species of *Siganus* should bear.

FAMILY MONACANTHIDÆ.

251. **Stephanolepis sulcatus** (Holland).
Keerun (Jordan & Evermann).

FAMILY TETRAODONTIDÆ.

252. **Tetraodon stellatus** (Bloch & Schneider).
One large specimen, fourteen inches long, from Takao.

253. **Spheroides lunaris** (Bloch).
(Native name *Gui hii.*)
Five specimens from Takao, ten to thirteen inches long.

254. **Spheroides ocellatus** (Osbeck).
Hokoto (Jordan & Evermann).

255. **Spheroides sceleratus** (Forster).
Hokoto (Jordan & Evermann).

FAMILY OSTRACIIDÆ.

256. **Ostracion cornutum** (Linnæus).
(Native name *Koh gong.*)
One large specimen from Takao, measuring seven inches in length to tip of tail.

Family DIODONTIDÆ.

257. **Diodon holacanthus** Linnæus.
Hokoto (Jordan & Evermann).

Family TRIGLIDÆ.

258. **Lepidotrigla alata** (Houttuyn).
(*Lepidotrigla bürgeri* Temminck & Schlegel.)
Hokoto (Jordan & Evermann).

Family CEPHALACANTHIDÆ.

259. **Dactyloptena japonica** (Bleeker).
Giran (Jordan & Evermann).

Family GOBIIDÆ.

260. **Eleotris oxycephala** Temminck & Schlegel.
One specimen from Takao, three and one-half inches long.

261. **Eleotris fusca** (Bloch & Schneider).
Suwata (Jordan & Evermann).

262. **Rhinogobius caninus** (Cuvier & Valenciennes).
Two specimens from Takao, three inches long.

263. **Rhinogobius giurinus** (Rutter).
Kotosho; Taihoku (Jordan & Evermann, as *Ctenogobius platycephalus*).

264. **Glossogobius brunneus** (Temminck & Schlegel).
Kotosho; Keerun (Jordan & Evermann).

265. **Glossogobius abacopus** sp. nov. (Plate LXXIV.)

Head to tip of lower jaw, 3 in length; depth 5.5; eye 4 in head; dorsal VI, 10; anal 10; scales 128–30; snout 3.5 in head; maxillary 2.4; interorbital space slightly greater than width of pupil. Body elongate, rather depressed in front, tapering gradually backward to the depressed caudal peduncle; depth of caudal peduncle 3.4 in head; head pointed; lower jaw projecting width of pupil; mouth large, maxillary reaching vertical from back of pupil; jaws, vomer, and palatines with rows of fine, sharp-pointed teeth; tongue deeply notched; origin of spinous dorsal nearly an eye-length behind insertion of ventrals, its base 2.4 in head; base of soft dorsal 1.5 in head; longest dorsal spine 2.25; longest ray 2 in head; origin of anal under second ray of soft dorsal, equidistant between base of caudal and back of eye; pectoral 1.3 in head; ventrals 1.4; depth of membranous cup of united ventrals $\frac{2}{3}$ of length of eye; caudal 1.3 in head, rounded; a large anal papilla with notch behind.

Color in spirits brownish-olive, back and caudal peduncle crossed obliquely by four broad saddle-like bands of darker color; membranes of dorsals and of anal chiefly blackish, with some small spot-like intervals of paler on these and on rays; caudal and ventrals dark barred or checkered; pectorals lightly specked with dusky, with darker and denser specks below at base; under parts unevenly punctulated, the dots forming indistinct bars on chin and lower jaws; tip of lower jaw blackish.

This species is near *Glossogobius vaisiganis* from Samoa, but differs distinctly in the details of coloration, notably in the sharply checkered ventral fin.

Described from four specimens from Takao, two and one-half inches long.

266. **Amblygobius phalæna** (Cuvier & Valenciennes).
Two specimens from Takao, three inches long.

267. **Amblygobius sphinx** (Cuvier & Valenciennes).
Three specimens from Takao, three to three and one-half inches long.

268. **Oxyurichthus papuensis** (Cuvier & Valenciennes).
Two specimens from Takao, three inches long.

269. **Oxyurichthus cristatus** (Day).
One specimen from Takao, three inches long. Scales 55; dorsal VI, 13; anal 14. The specimen seems to differ from specimens of this species from the Philippines in having a slightly larger mouth, and may not be the same.

Family ECHENEIDÆ.

270. **Remora remora** (Linnæus).
Two specimens from Takao, six inches long.

Family PLEURONECTIDÆ.

271. **Psettodes erumei** (Bloch).
(Native name *Bin hii.*)
One fine specimen from Takao, twelve inches long.

272. **Pseudorhombus oligodon** (Bleeker).
Four specimens from Takao, seven inches long.
Formosa (Jordan & Evermann).

273. **Platophrys myriaster** (Temminck & Schlegel).
Keerun (Jordan & Evermann).

274. **Scæops orbicularis** (Bleeker).
A very small specimen from Takao, two inches long, is probably this species.

Family SOLEIDÆ.

275. **Liachirus nitidus** Günther.
Giran (Jordan & Evermann).

276. **Synaptura orientalis** (Bloch and Schneider).
(*Synaptura foliacea* Richardson.)
Formosa (Jordan & Evermann).

277. **Usinosita japonica** (Temminck & Schlegel).
Keerun (Jordan & Evermann).

278. **Paraplagusia bilineata** (Bloch).
Keerun (Jordan & Evermann).

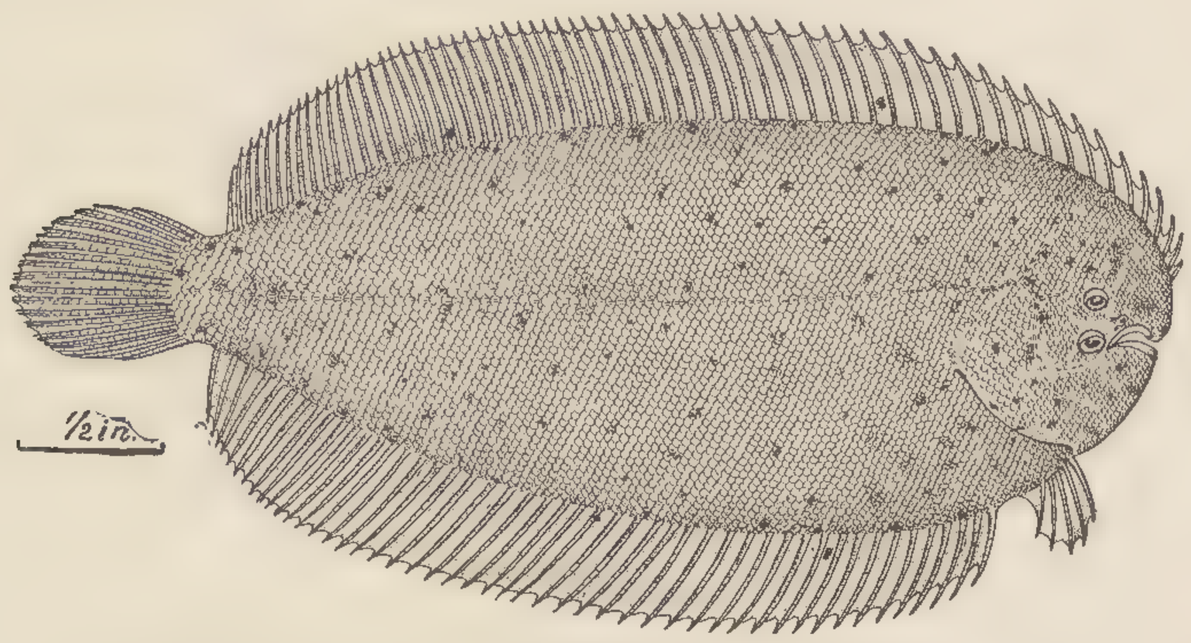


FIG. 24. *Liachirus nitidus* Günther. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 366.)

279. **Cynoglossus diplasios** Jordan & Evermann.
Formosa (Jordan & Evermann).

FIG. 25. *Cynoglossus diplasios* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 367.)

280. **Zebrias zebra** (Bloch).
Formosa (Jordan & Evermann).

Family CALLIONYMIDÆ.

281. **Callionymus schaapii** Bleeker.

Head 3.2; depth 9; dorsal IV, 10; anal 9. Body moderately elongate, broader than deep and tapering gradually backward. Head broad, much depressed, its width two-thirds of its length, its depth 3 in its width; snout bluntly pointed, scarcely longer than eye; eyes close together, $4\frac{1}{2}$ in head; mouth small, inferior, the upper jaw projecting, maxillary reaching half way to orbit; jaws with bands of villiform teeth; preopercular spine with four or five strong teeth and sometimes a

rudiment directed upward, besides the hook at tip, and a sharp spine projecting forward from its base; occipital region weakly rugose; gill-opening about one-fourth diameter of eye, about equidistant between back of eye and origin of dorsal. Spinous dorsal inserted midway between back of eye and origin of soft dorsal; first and fourth dorsal spines longest, the first (specimens females) $2\frac{1}{3}$ in head; height of soft dorsal at its middle about one-third length of head; last ray elongated, about $1\frac{1}{4}$ in head; anal beginning a little behind second ray of soft dorsal; last ray of anal $2\frac{1}{2}$ in head; pectoral $1\frac{1}{4}$ in head, its median rays longest; ventrals reaching past origin of anal; caudal as long as head, its middle rays not produced; caudal peduncle depressed; lateral line single.

Color in spirits olive, rather heavily punctulated above, the punctulations on the back of the head and on the back as a rule encircling paler areas, some of which are more or less confluent; under parts pale; spinous and soft dorsals rather faintly splashed and specked with dusky; anal with a basal and a marginal row of brown blotches, the basal row smallest; ventrals dusky, brown-dotted on inner two-thirds; upper pectoral rays with dark specks.

Described from two specimens from Takao, two and one-half to three inches long, probably females.

This species is near and perhaps not different from *Callionymus schaapii* Bleeker described with dorsal IV–10, anal 10, six processes on preopercular spine, and with ventrals and anal black-edged. There is no point in which our species clearly differs from the scanty account given by Bleeker, whose specimen was from Banka.

Family BLENNIIDÆ.

282. **Salarias namiyei** Jordan & Evermann.

Hokoto or Pescadores Islands (Jordan & Evermann).

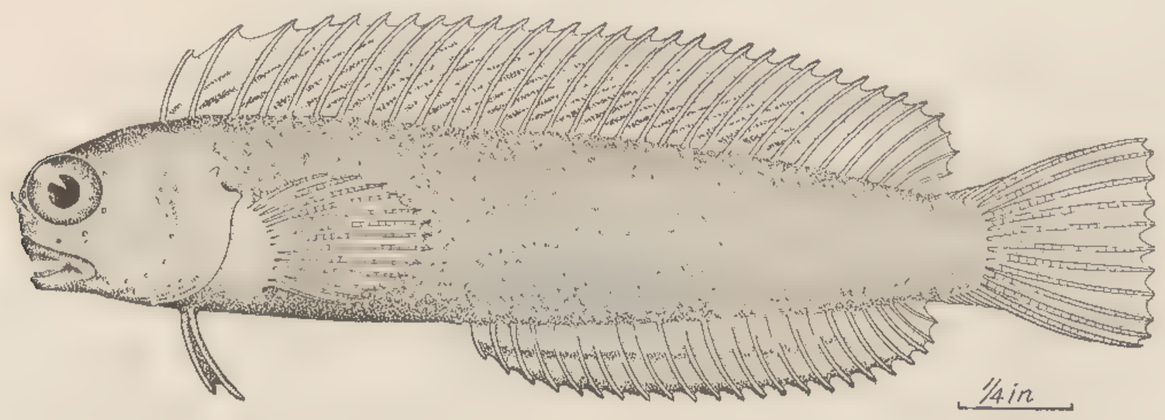


FIG. 26. *Salarias namiyei* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 362.)

Family CEPOLIDÆ.

283. **Acanthocepola mesoprion** Bleeker.

Giran (Jordan & Evermann).

FIG. 27. *Acanthocepola mesoprion* Bleeker. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 363.)

Family AMMODYTIDÆ.

284. **Embolichthys mitsukurii** (Jordan & Evermann).

Giran (Jordan & Evermann, as *Bleekeria mitsukurii*).

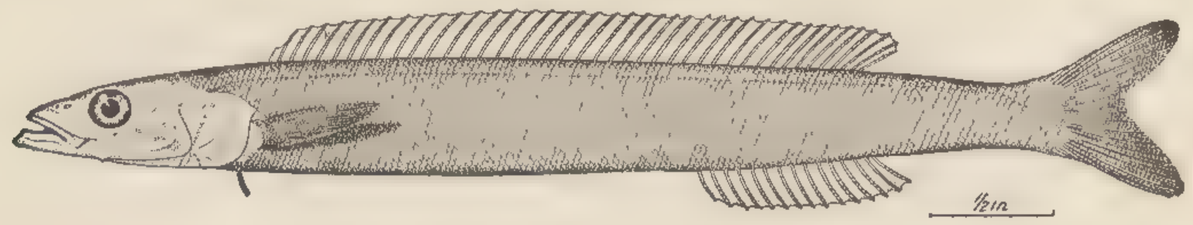


FIG. 28. *Embolichthys mitsukurii* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 334.)

Family BROTULIDÆ.

285. **Brotula multibarbata** Temminck & Schlegel.

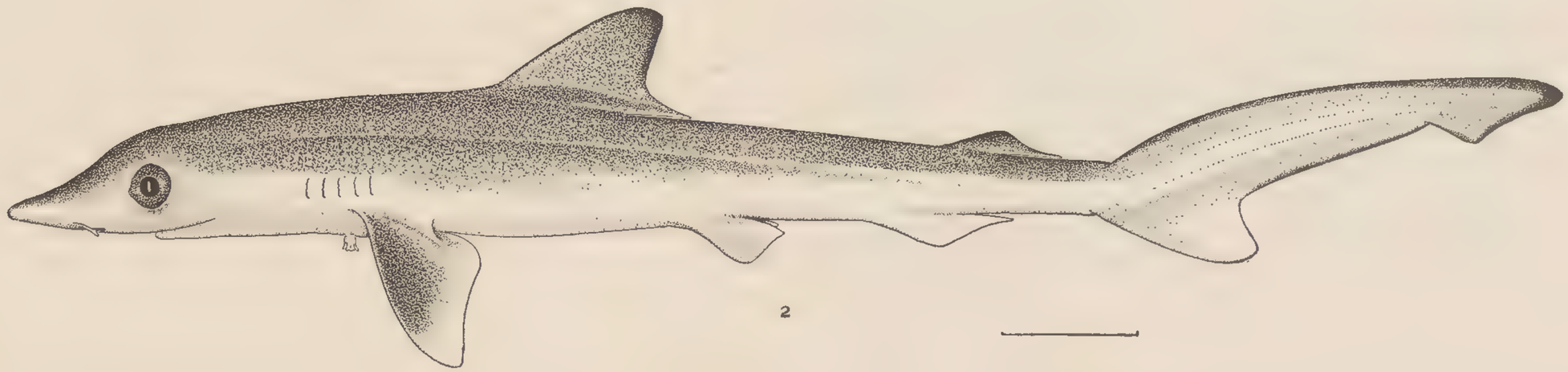
Two specimens from Takao, fifteen inches long.

286. **Brotula formosæ** Jordan & Evermann.

Formosa (Jordan & Evermann).

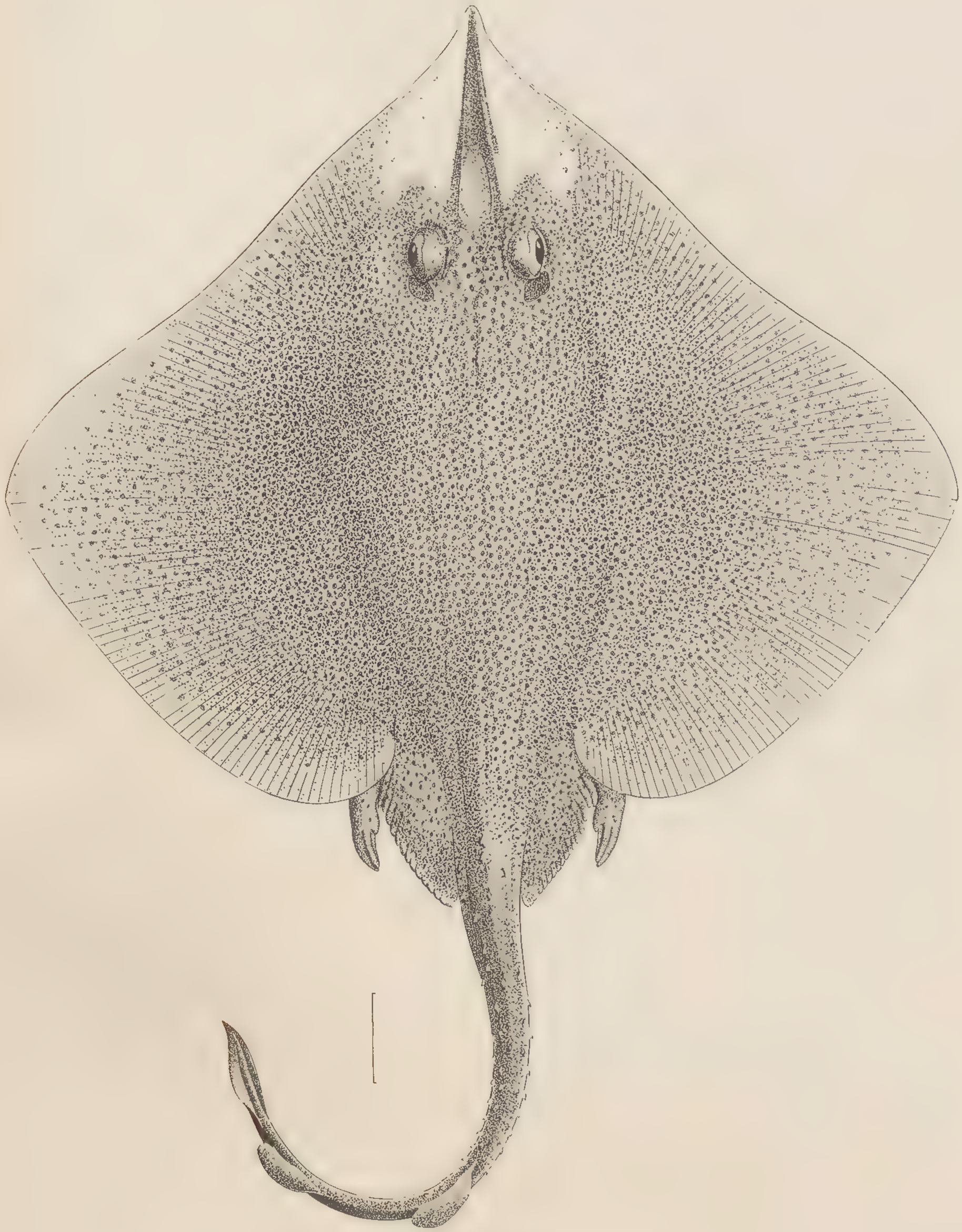
FIG. 29. *Brotula formosæ* J. & E. (After Jordan & Evermann, Proc. U. S. N. M., Vol. 25, p. 364.)

1



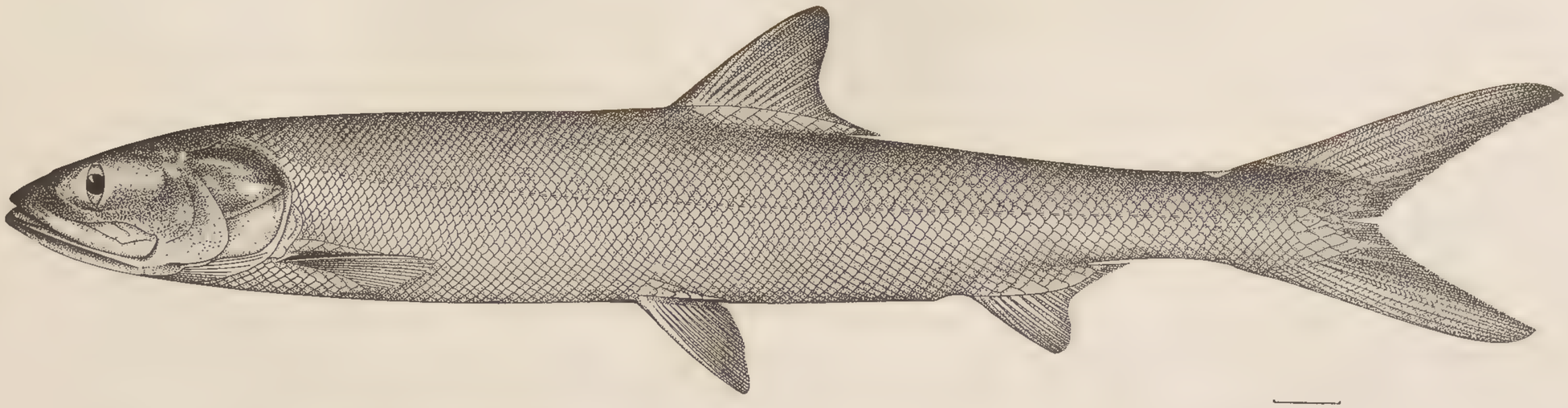
2

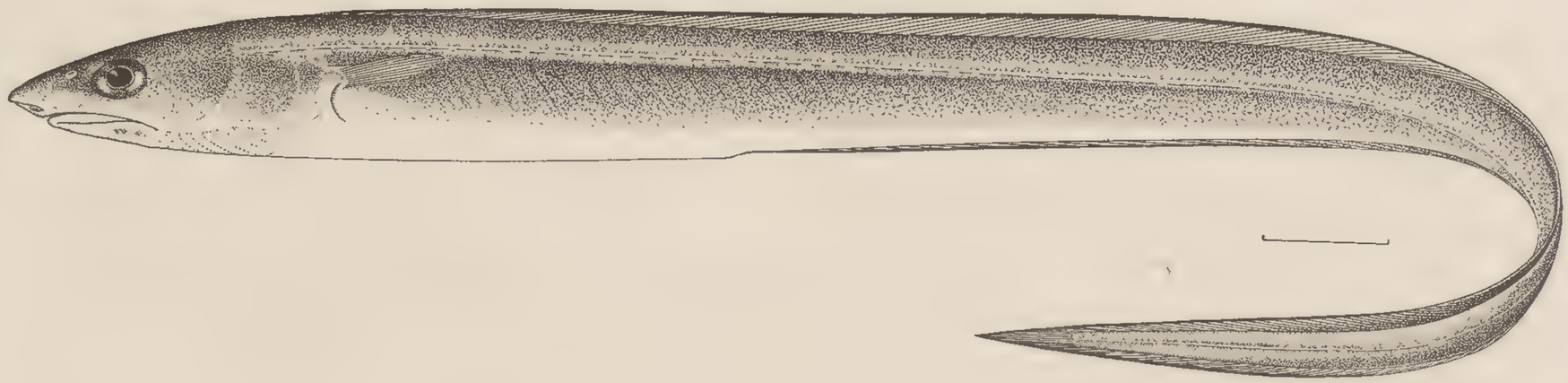
1. PRISTIURUS SAUTERI Jordan & Richardson. (Type.) 2. SCOLIODON WALBEEHMI (Bleeker).



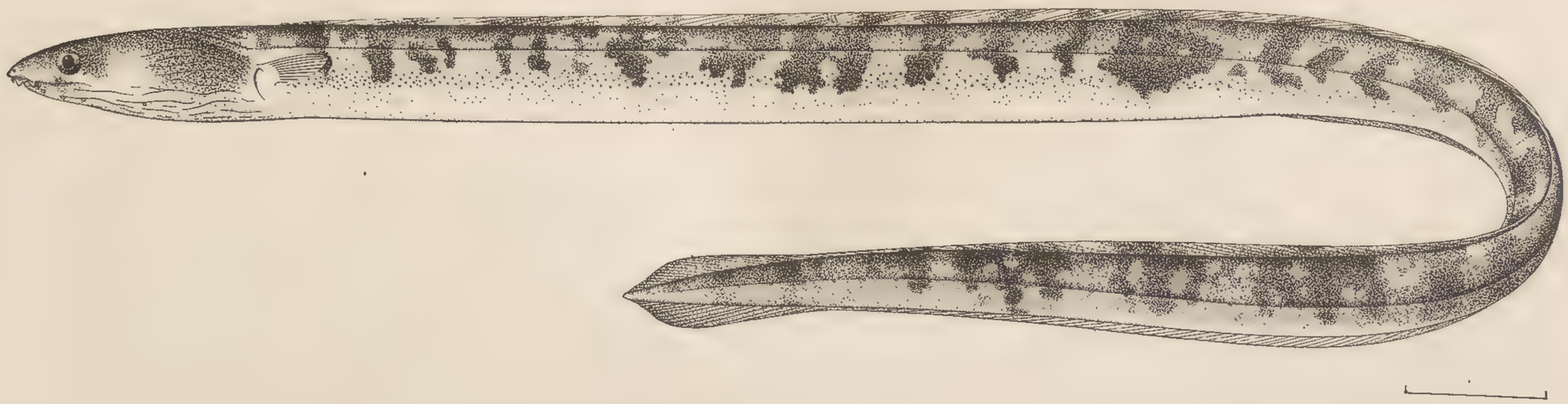
RAJA HOLLANDI Jordan & Richardson. (Type.)

DASYATIS BENNETTI (Müller & Henle) (?).

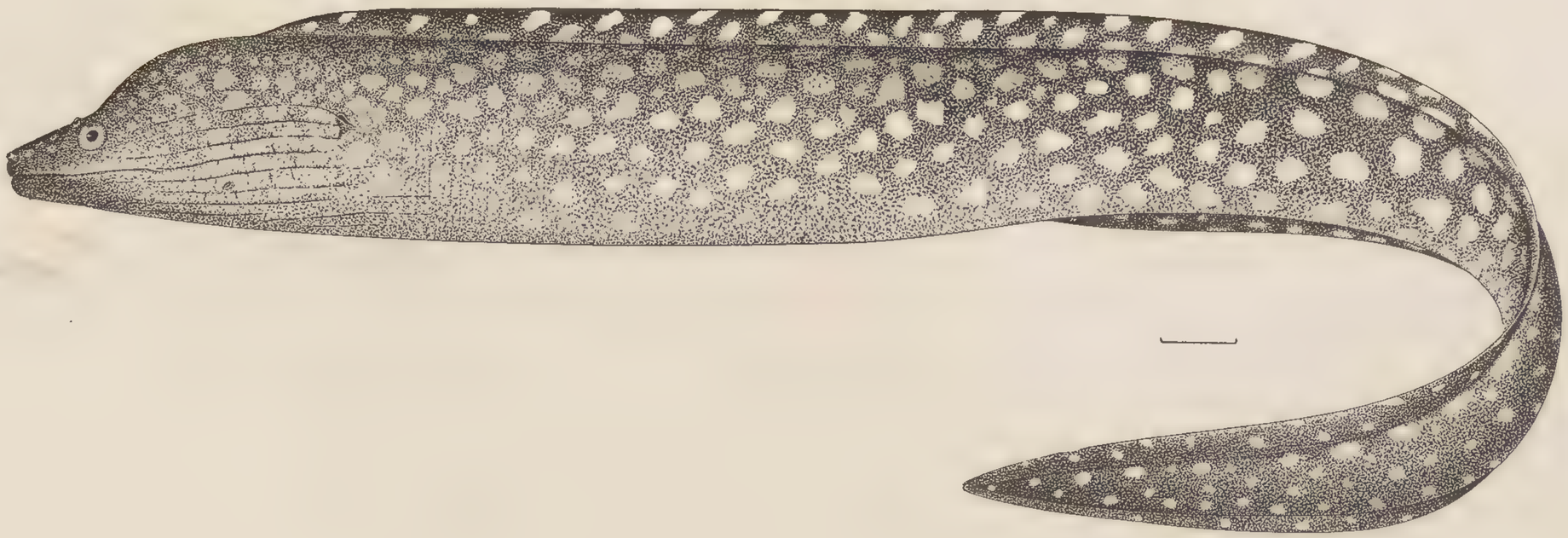




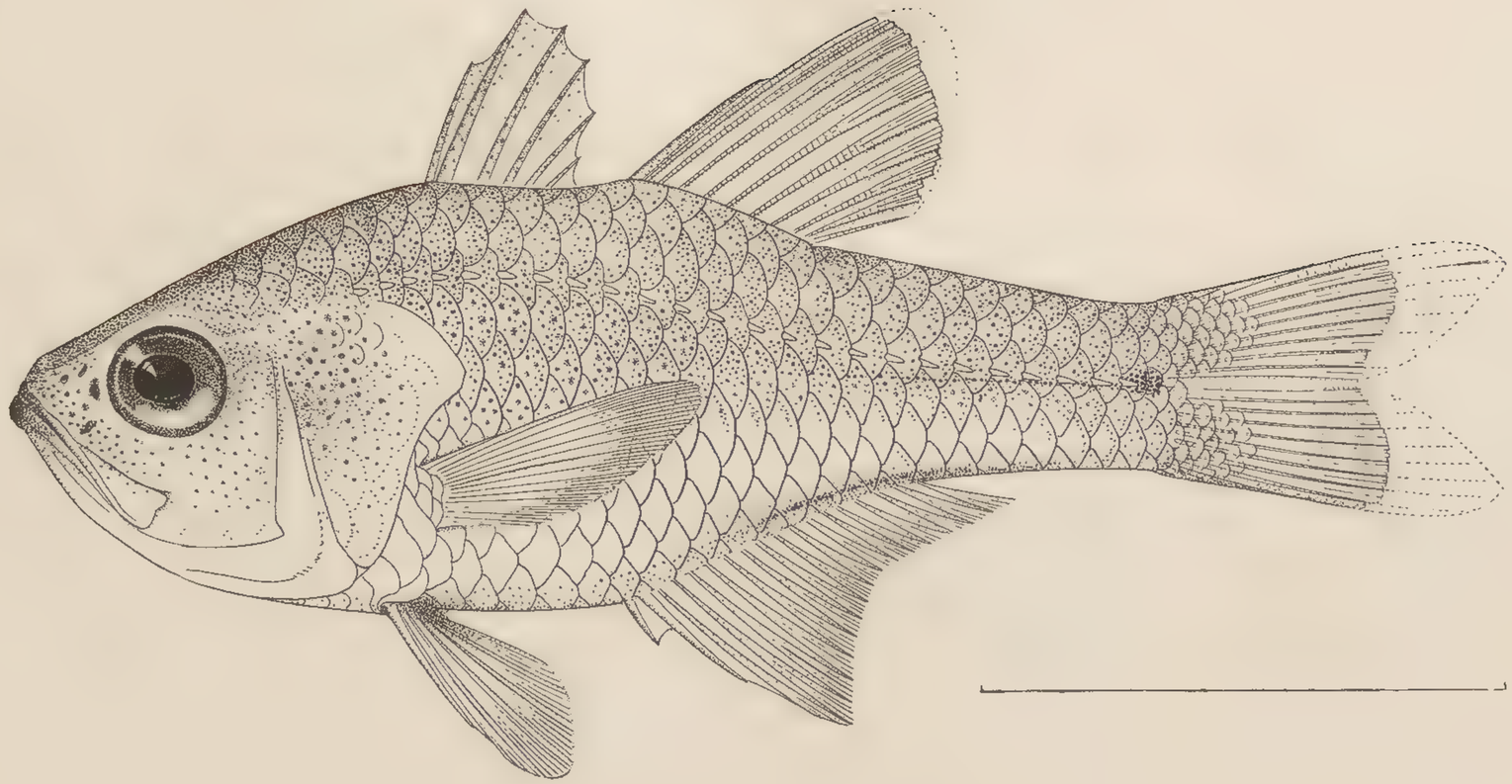
ELOPS HAWAIIENSIS Regan. LEPTOCEPHALUS ECTENURUS Jordan & Richardson. (Type.)



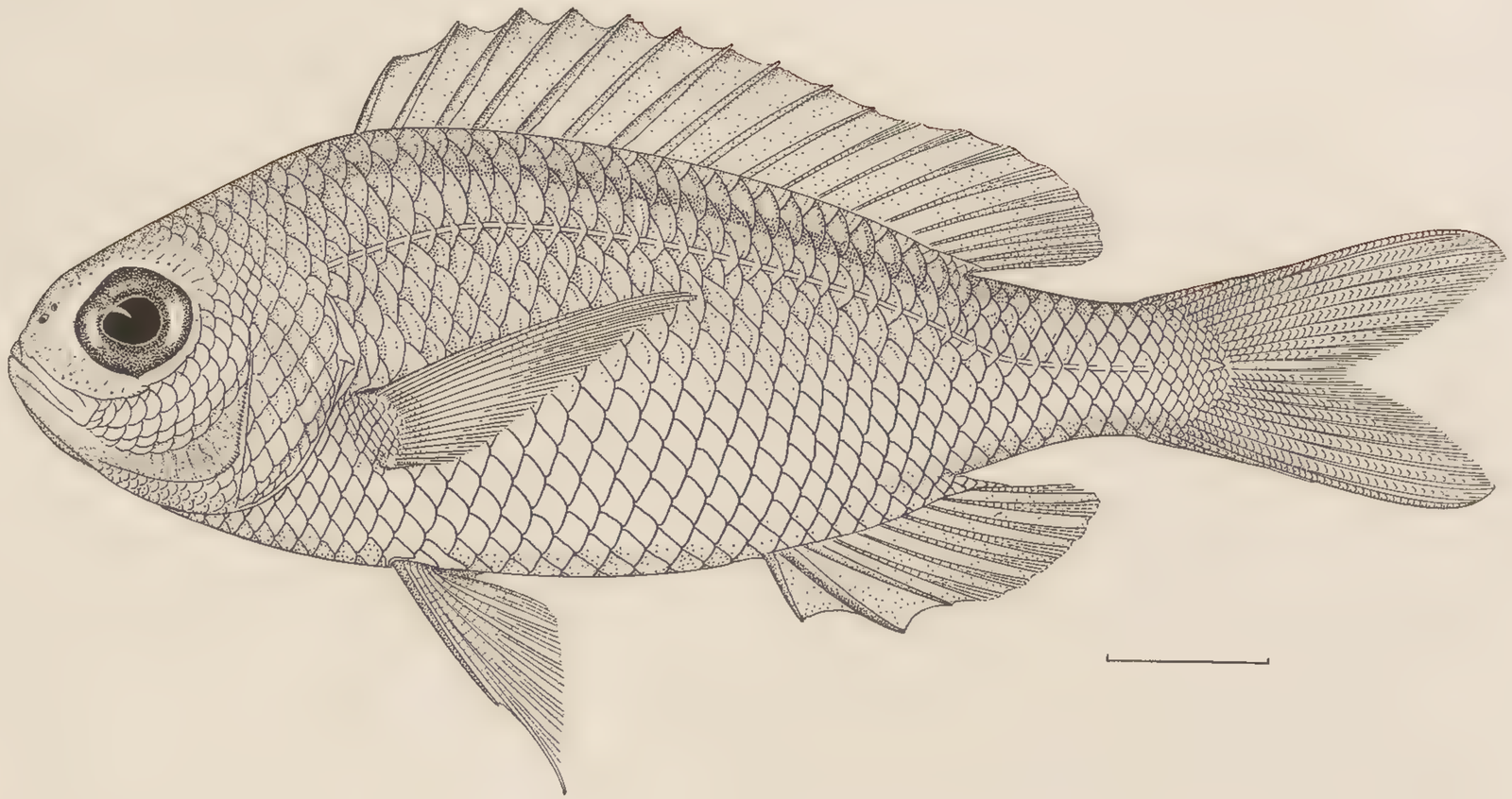
OPHICHTHUS EVERMANNI Jordan & Richardson. ½ (Type.) GYMNOTHORAX MELANOSPILOS (Bleeker).



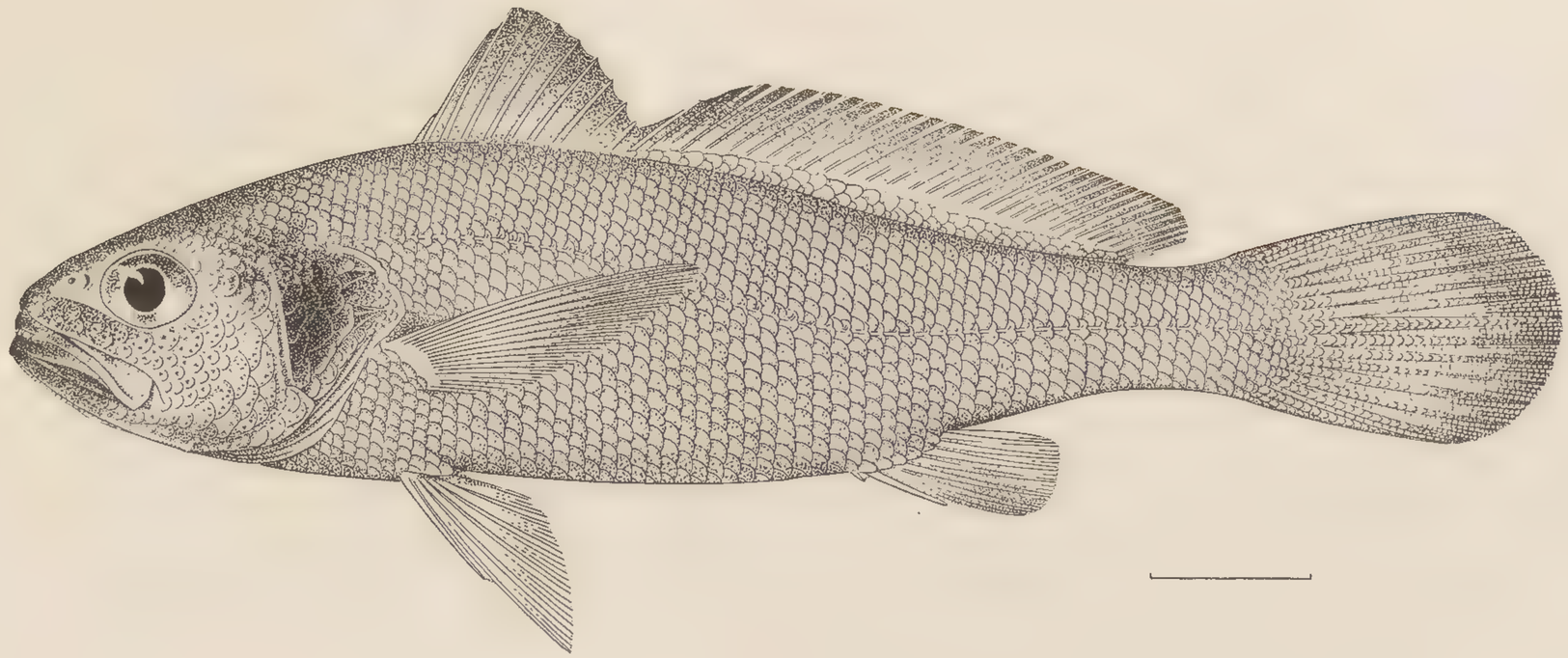
GYMNOTHORAX LEUCOSTIGMA Jordan & Richardson. (Type.)



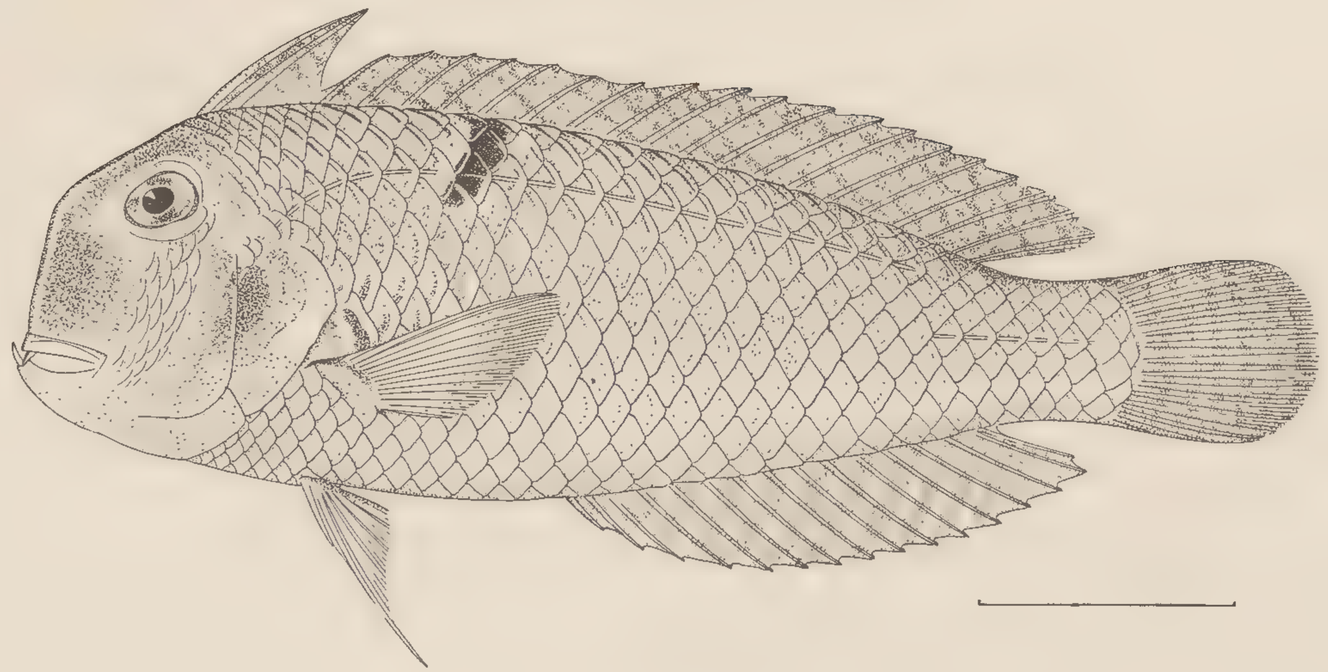
ARCHAMIA NOTATA (Day).



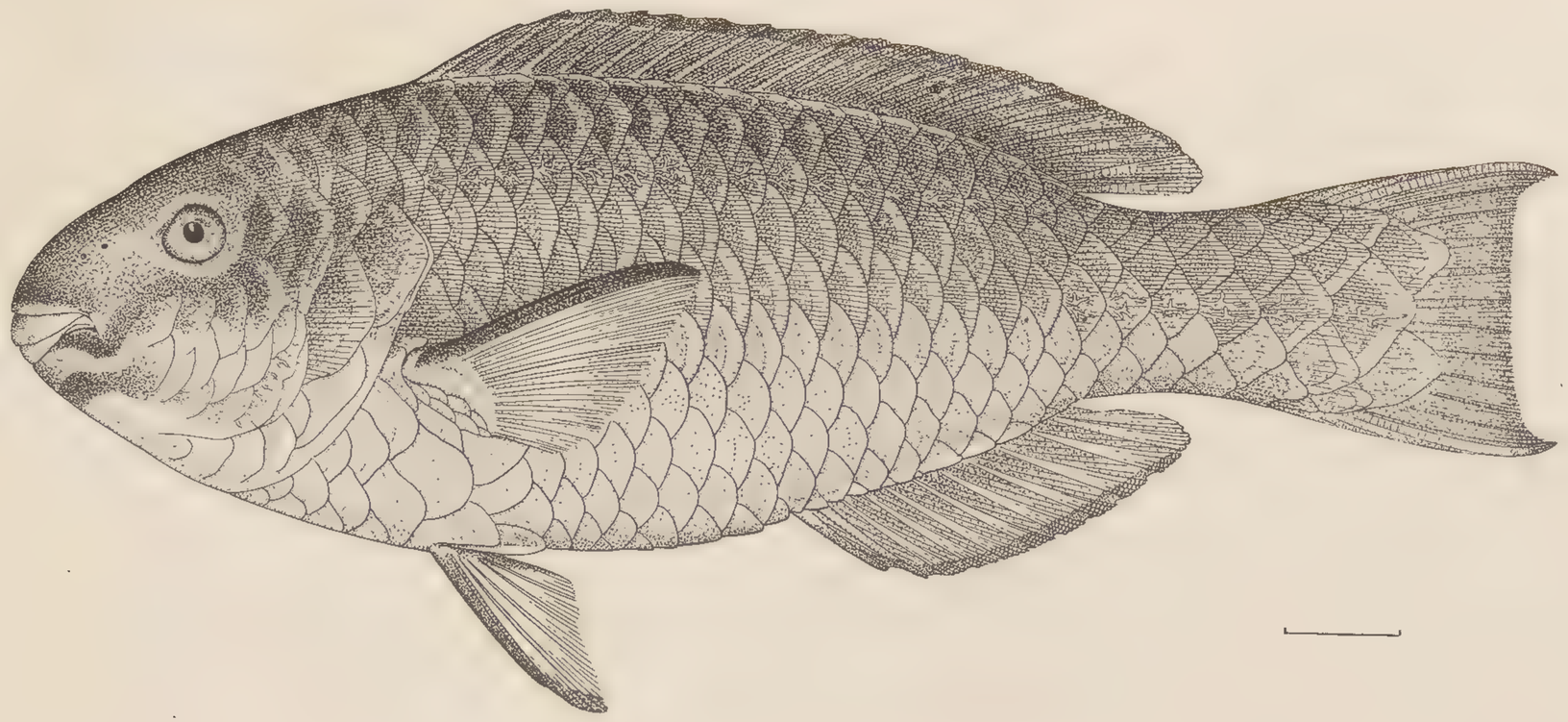
SCOLOPSIS ERIOMMA Jordan & Richardson. (Type.)



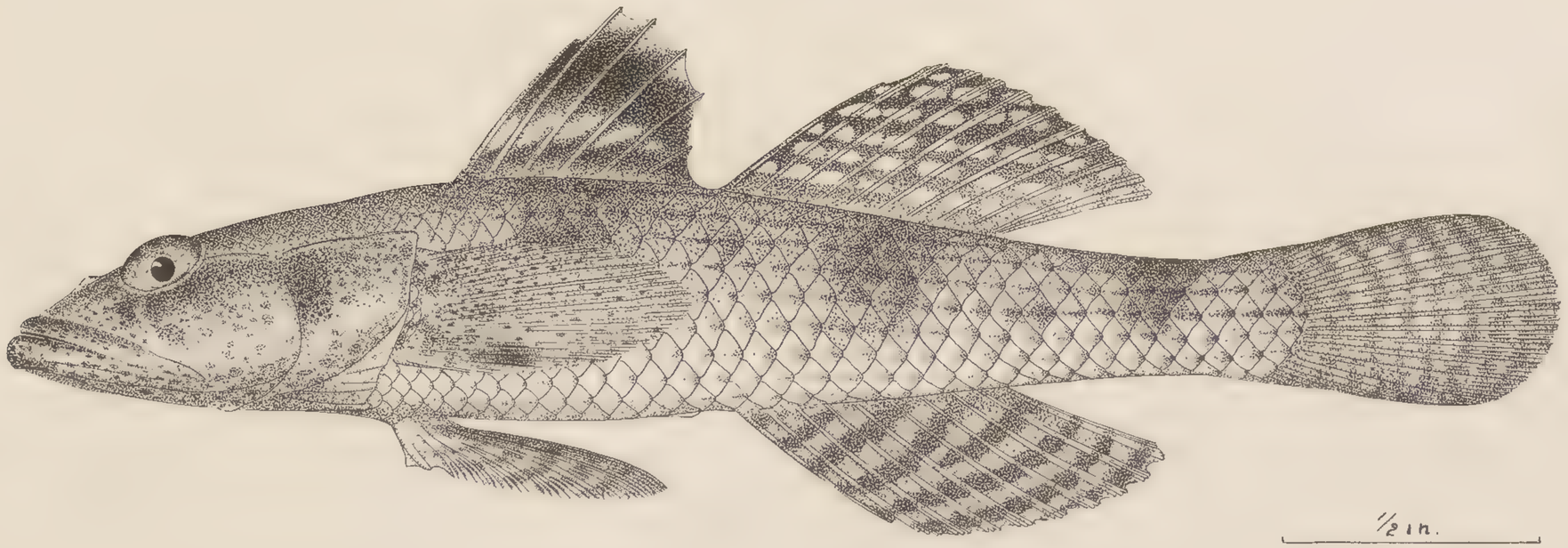
PSEUDOTOLITHUS BRUNNEOLUS Jordan & Richardson. (Type.)



HEMIPTERONOTUS EVIDES Jordan & Richardson. (Type.)



CALLYODON DUSSUMIERI (Cuvier & Valenciennes).



GLOSSOGOBIUS ABACOPUS Jordan & Richardson. (Type.)

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OF THE

CARNEGIE MUSEUM.

VOL. IV. NO. 5.

W. J. HOLLAND, EDITOR.

DESCRIPTION OF NEW CARNIVORES FROM THE MIOCENE OF WESTERN NEBRASKA.

BY O. A. PETERSON

PITTSBURGH.

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Errata et Corrigenda.

Page 227, lines 3 and 4 from top, *for* "especially in the latter" *read* "especially the latter."

Page 229, line 8 from top, *for* "vertebra," *read* "vertebræ."

Page 251, last line, *for* "fibular" *read* "tibial."

Page 255, line 3 from bottom, *dele* "the."

Page 257, line 19 from bottom, *for* "Oligocence," *read* "Oligocene."

Page 260, line 3 from top, *for* "Paradaphœnus" *read* "Paradaphænus."

Page 261, line 9, *for* "Cynadesmus" *read* "Cynodesmus."

Page 263, last line, *for* "posteriar" *read* "posterior."

Page 277, lines 9 and 10 from top, *for* "Brachygale" *read* "Sthenictis."

Page 278, line 5 from the bottom, *for* "Melivoradon" *read* "Melivorodon."

Page 278, line 2 from bottom, *for* "Brachygale" *read* "Sthenictis."

MEMOIRS

OF THE

CARNEGIE MUSEUM.

VOL. IV. NO. 5.

DESCRIPTION OF NEW CARNIVORES FROM THE MIOCENE OF WESTERN NEBRASKA.

By O. A. Peterson.

While prospecting in the layer of fossil bones, which is exposed around "Carnegie Hill" and "University Hill" in the Miocene formation on the upper Niobrara River in Sioux County, Nebraska, with a view to opening additional quarries,[1] the writer, assisted by Messrs. T. F. Olcott and A. A. Dodd, was extremely fortunate in finding in what is now called Quarry No. 3 (see Fig. 1, 3) various

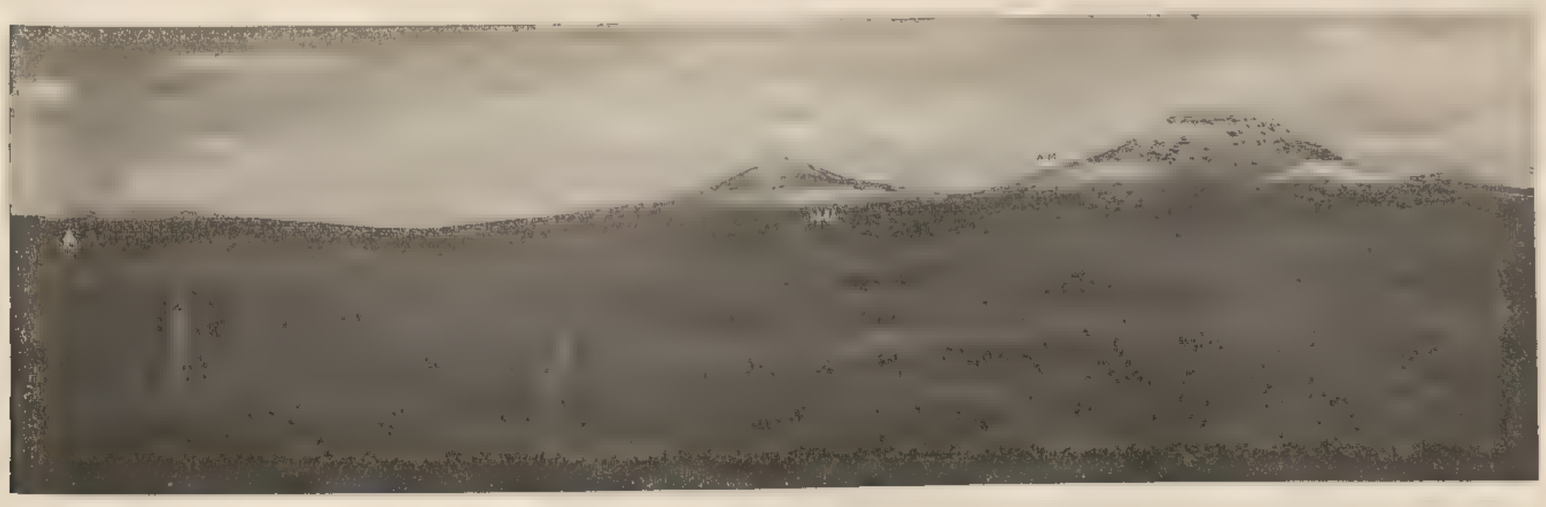


Fig. 1. Agate Spring Fossil Quarries. 1–2, quarries Nos. 1 and 2, on Carnegie Hill; 3, quarry No. 3; AM, American Museum quarry on Carnegie Hill; NU, Nebraska State University quarry on University Hill; A, quarry A. (From a photograph by the author.)

remains of carnivora, among which is a nearly complete skeleton of a canid. The material having been entirely freed from the matrix and prepared for mounting by the skillful work of Mr. S. Agostini, the writer was entrusted by Director W. J. Holland with the task of describing and illustrating the new material.

[1] No quarries except quarry A had at that time (1904) been opened in these hills.

In the quarry designated as No. 3 in the accompanying illustration, there were found from five to nine individuals of *Daphœnodon superbus*, of which No. 1589 is practically a complete skeleton. The latter was found imbedded together with another individual of the same species not fully adult. The soft sandstone in which the two were found was taken out in a large block and transported to the Museum. On examination it was found that the adult individual was partly articulated, especially the vertebral column and portions of the feet. The tail was found attached to the sacrum and thrown backward in a graceful curve so that the tip was lying close to the pelvis and abdominal region. The anterior nine vertebræ and the anterior portion of the tenth were preserved in position. At this point the caudal region had been exposed and the vertebræ had dropped out. By carefully measuring the natural curve, in which the tail was undoubtedly placed, its length was ascertained and the missing vertebræ were either restored in plaster, or by other vertebræ which were found in the talus below the place where the skeletons were dug out. The ribs of No. 1589 are not well preserved while those of the younger individual, No. 1589a, are quite complete. The posterior portion of the sternum is not present. One hind limb and foot of No. 1589 was found articulated.

The posterior portion of the pelvis is weathered away, as is also the extreme anterior portion, leaving only the middle region. When material other than the type is used in the following description it is only for the purpose of elucidation and the catalog number will be mentioned in connection with the specimens referred to in order to prevent confusion.

Scattered remains of a number of individuals, apparently of the same species, were found in all of the Agate Spring Fossil Quarries, but in Quarry No. 3 were found the most abundant remains of *Daphœnodon superbus.* Besides the type of *Nothocyon annectens* Peterson and another small carnivore described later in this paper there was little else found in Quarry No. 3 except remains of *Daphœnodon superbus.* This is interesting from the fact that hardly more than a stone's throw to the north and practically on the same level, the very rich and classic quarries, No. 1, No. 2, and the "University Quarry" are located (see Fig. 1). The lithological characters of the bone layer of Quarry No. 3 are similar to those in the large quarries and it was observed that the same barren pinkish bedrock found in the main quarries is also present in this quarry. The irregularity of the fossil-bearing stratum was observed to be quite like that in the quarries immediately to the north. As has been stated elsewhere, the stratum containing fossil bones in the Agate Spring Fossil quarries was most probably laid down by a stream full of shallow channels which shifted from time to time during its existence.

Much field-work has been done and a considerable amount of material representing the carnivora has been found in the lower and middle Miocene of South Dakota, western Nebraska, eastern Colorado and Wyoming during the past few years by the different museums of North America.[2] Since further explorations of this region are likely to occur in the near future it has seemed best to postpone a more detailed and systematic work upon the carnivora of these localities and for the present only to publish the new forms recently found by the museum parties and especially to accurately describe the skeleton of *Daphœnodon superbus*. It is believed that the study of the lower Miocene Canidæ will be facilitated by the publication of an account of the nearly complete skeleton of one individual.

In the following description the exceptionally well preserved and almost complete skeleton of *Daphœnus felinus* Scott (No. 492, Carnegie Museum Catalog of Vertebrate Fossils) which Mr. J. B. Hatcher described (Memoirs Carnegie Museum, Volume I, pp. 65–108) will be used for comparison. In the first place it seems quite certain that *Daphœnus* is in the direct ancestral line of *Daphœnodon*, and secondly, the skeleton from the Oligocene now in the Carnegie Museum, represents the most complete individual of that genus as yet discovered.

Valuable aid in this work was rendered by the authorities of the American Museum of Natural History and of Princeton University Museum, who courteously sent to the Carnegie Museum a number of types for comparison. The illustrations are from drawings made by Mr. Sydney Prentice and photographs by Mr. A. S. Coggeshall and the author.

Family CANIDÆ.

Subfamily AMPHICYONINÆ.

Daphœnodon superbus (Peterson).

Amphicyon superbus Peterson, Annals Carnegie Museum, Vol. IV, pp. 51–53, Pl. XVIII, 1908. *Daphœnodon superbus* (Peterson), *Science*, N. S., Vol. XXIX, pp. 620–621.

Type: Skeleton nearly complete, No. 1589, Carnegie Museum Catalog of Vertebrate Fossils.

Horizon: Miocene (Lower Harrison Beds).

Locality: Agate Spring Fossil Quarries (Quarry No. 3), Sioux County, Nebraska.

Distinctive characters. — In my previous notes in *Science* I gave the following distinctive characters: *Cranium comparatively short, broad, and low; muzzle large;*

[2] Professor F. B. Loomis, of Amherst, recently discovered two miles east of the Agate Spring Fossil Quarries the greater portion of a fine skeleton which he regards as belonging to the same genus described below.

sagittal crest prominent; brain-case small; incisors heavy and short; canines comparatively small and oval in cross-section; P^4 with antero-internal cusp of moderately large size and located relatively close to the main body of the teeth; M^1 and M^2 large and broad; M^3 present, though small, practically one-rooted and aligned with the internal border of M^1 and M^2. To the above cited characters should be added: $I\frac{3}{3}$ $C\frac{1}{1}$ $P\frac{4}{4}$ $M\frac{3}{3}$; *the symphysis of the inferior ramus separated or slightly coössified; the tubercles of all the molar-premolar teeth blunt; the heel of the lower carnassial tooth large: metatarsals not appressed at their proximal ends; feet sub-digitigrade; tail long and heavy.*

The Skull.

(Plates LXXIV–LXXVII.)

In the articles cited above attention was paid to the cranial and dental characters of *Daphœnodon superbus.* In the present paper, therefore, I will only give a short review of my previous description and add characters which I regard as of interest and importance to the student.

The cranium of this new genus represents an animal very nearly as large as a fully adult gray wolf, but the skull is proportionally shorter and broader, the brain-case smaller, the occipital condyles smaller, the basioccipital and basisphenoid of greater transverse diameter, the paroccipital process further separated from the tympanic bulla and directed more backward, the mastoid larger, the tympanic bulla smaller, and the postglenoid process heavier. When compared with *Daphœnus felinus* the skull is distinctly shorter and broader but the brain-case is evidently not much enlarged and there is a large frontal sinus; the muzzle is heavier; the pterygoids are shorter, and the region back of the pterygoids is apparently also somewhat shortened. The postglenoid and paroccipital processes are of the same relative size and position while the mastoid process is a truncated rounded knob, and is of proportionally greater size. In fact the entire mastoid region of *Daphœnodon* seems to have increased, which is a distinct step away from the line of *Canis.* The space between the paroccipital process and the condyles is shorter, so that the occipital condyles are more sessile in the specimen under description than in the Oligocene genus.[3] The tympanic bullæ are present on both sides in the type specimen; they are of moderately large size and triangular in general outline. The tubular process, which encloses the external auditory meatus is quite prominent and is protected posteriorly by the heavy mastoid, though not so completely coössified with the latter bone as in the recent dogs. On the postero-internal angle of the bulla there is a sharp vertical ridge which unites with a similar though much

[3] In *Daphœnus felinus* (No. 492, C. M. Cat. Vert. Foss.) the base of the skull in the region of the condyles is somewhat injured and the separation of the condyle from the paroccipital process may, in part, be due to this fact.

heavier ridge on the antero-internal angle of the paroccipital process, thus separating the large pit for the tympanohyal externally, the jugular foramen, and the foramen lacerum posterius internally. The bulla seems to be fairly well fused to the tympanic region while in the Oligocene genus it apparently always slipped off. From a study of the tympanic bulla in *Daphœnodon superbus* it is quite evident that though quite solidly attached along the antero-external angle and along the border of the basioccipital, the bone is not nearly so well ankylosed by the paroccipital process and the mastoid as for instance in *Canis*. In *Daphœnus felinus* the bulla appears to be more loosely attached to these processes than in the type under description. This fact apparently supports Mr. Hatcher's contention that the ankylosed auditory bulla in recent dogs should be regarded as a specialized character.[4]

It is interesting to note that the tympanic bulla in *Cynodesmus brachypus* (Cope) is, in the first place, larger; and, secondly, much better ankylosed with the surrounding bones than in the form under description, and more nearly approaches that of *Canis*. Professor Cope[5] and Dr. Matthew[6] have observed that the paroccipital process in *Cynodesmus brachypus* projects "backwards nearly as far as the posterior face of the occipital condyles." After a careful study of this region in the type of *Cynodesmus brachypus*, now before me, it would seem that the backward projection of the paroccipital process, regarded as a primitive character by Matthew, is in reality due very largely to crushing, there being no part of the base of the skull which is left undisturbed. Besides, if the present position of the paroccipital process of the skull of *C. brachypus* is a natural one it would interfere with the free movement of the occipital condyle upon the atlas. Unfortunately the paroccipital process of the left side of *C. brachypus* has been broken off, which otherwise might have furnished good verification. From Dr. Matthew's statement and illustrations (*l. c.*) it is very evident that the paroccipital process in *Cynodesmus thomsoni* is closely connected to the tympanic bulla and points almost directly downward at the tip, while in *Cynodesmus thoöides* Scott[7] the process is heavy and projects more backward. It is quite likely that in a more perfect specimen of *C. brachypus* the condition of the paroccipital process would be found to be more like that in *C. thomsoni* and certainly not more backwardly directed than in *C. thoöides*. The postglenoid process of *C. brachypus* has proportionally a less transverse diameter than in *Daphœndon superbus* and is more nearly similar to that of *Canis*, while the foramen opticum occupies a similar position, *i. e.*, more in advance of the exit of the foramen rotundum than in recent dogs.

[4] "Oligocene Canidæ," MEMOIRS CARNEGIE MUSEUM, Vol. I, pp. 72–73, 1902.

[5] Bull. U. S. Geological and Geographical Survey of the Territories, Vol. VI, p. 389, 1881.

[6] Bull. Am. Mus. Nat. History, Vol. XXIII, p. 186, 1907.

[7] Trans. Am. Philos. Society, Vol. XVII, p. 66, Pl. I, fig. 1893.

In the type under description the greater number of the foramina are well preserved. With the exception of the more internal position of the stylomastoid foramen [8] and the slightly more anteriorly placed foramen opticum, the size and position of the foramina are quite similar to those of *Canis*, which is well illustrated in Plate LXXV. The more internal position of the stylomastoid foramen is due to the large development of the mastoid process and limited backward extension of the tympanic bulla, while the position of the optic foramen may be due to the more advanced position of the orbit in *Daphœnodon* than in *Canis*. The alisphenoid canal is apparently larger in proportion than in the Oligocene genus.

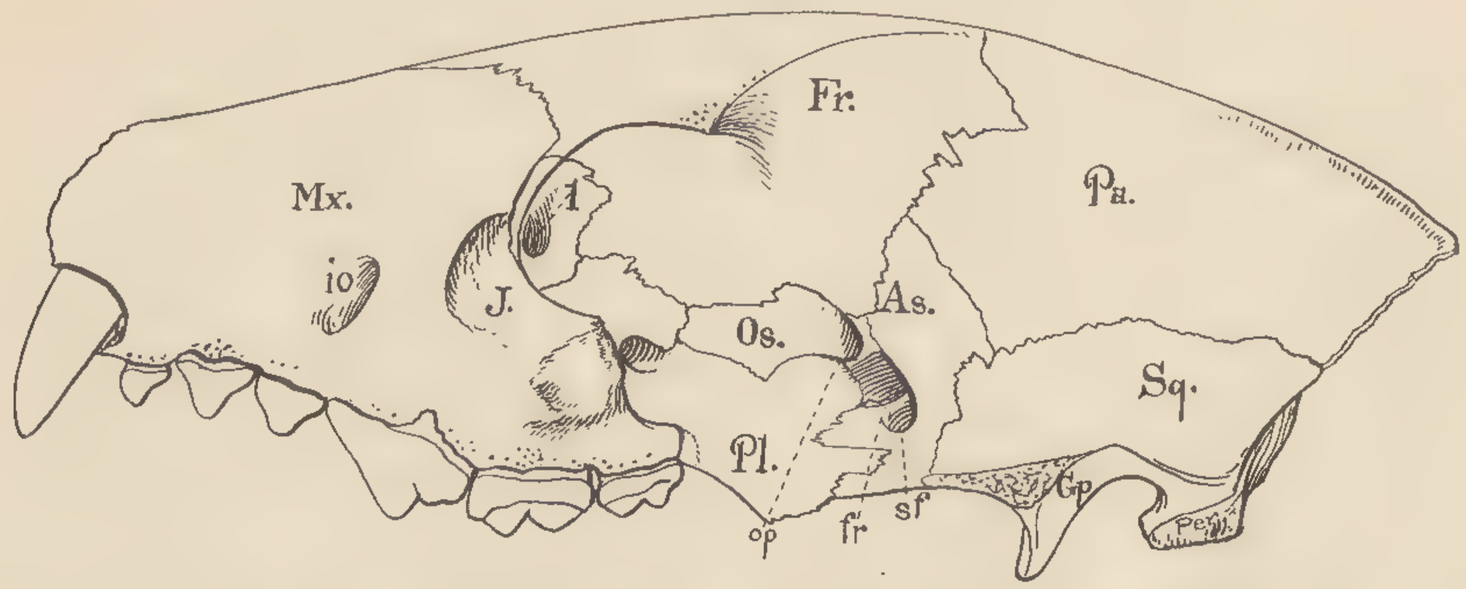


FIG. 2. Skull of young individual of *Daphœnodon superbus*. $\frac{2}{3}$ nat. size. No. 1589a, C. M. Cat. Vert. Foss. *Per*, mastoid portion of periotic; *Gp*, postglenoid process; *J*, jugal; *Pl*, palatine; *Sq*, squamosal; *Pa*, parietal; *Fr*, frontal; *As*, alisphenoid; *Os*, orbitosphenoid; *l*, lachrymal with foramen; *Mx*, maxillary; *io*, infraorbital foramen; *op*, optic foramen; *fr*, foramen rotundum; *sf*, sphenoidal fissure. (Note: The occipital plate, the jugal, the nasals and the premaxillaries are missing and a portion of the zygomatic arch is removed in order to give a better view of the different elements of the skull in this region.)

In Fig. 2 is given a side view of the skull of the younger individual (1589a) which was found together with the type. The premaxillary, nasal, malar, supraoccipital, and the base of the skull are slipped off and lost, but what remains furnishes an admirable idea of each element and their relative proportions in comparison with those in *Canis*. It is seen that the parietal and frontal are longer, lower, and less convex; the alisphenoid of apparently the same proportion; the orbitosphenoid as long, but of less vertical diameter; the lachrymal larger; and the maxillary shorter than in the recent form. From the type specimen the process of the premaxillary, which extends upward between the maxillary and the nasal, is much shorter and weaker than in *Canis* and in this respect more nearly similar to what is observed in *Daphœnus*.

[8] The stylomastoid foramen is not nearly so well separated from the large pit for the tympanohyal as is generally the case in recent dogs.

Lower jaw.—The mandible is quite similar to that of *Canis lupus* in its general characters, but may better be compared with such a form as *Lycaon* on account of its broader symphysis and condyles. The alveolar border is, however, more completely taken up by the premolars in the latter form than in the fossil. There are two mental foramina: one directly below $P_{\overline{2}}$ and the other below $P_{\overline{3}}$. The inferior border of the horizontal ramus is less curved fore-and-aft than in *Daphœnus*, while the line of the alveolar border is about the same. The temporal fossa is broad and deep, the coronoid process large and the process of the angle very robust and more inflected than in *Daphœnus* or the recent forms.

Aside from the large pit, which lodged a considerable sized tympanohyal in the skull, the hyoid arch is not known in *Daphœnodon superbus*.

MEASUREMENTS OF SKULL AND JAWS.

	Mm.
Greatest length of skull	253
Distance from occipital condyle to incisors	228
Distance from occipital condyle to M^3	112
Distance from M^3 to and including the incisors	117
Greatest transverse diameter of the skull	148
Transverse diameter of occipital condyle	46
Greatest transverse diameter of the brain case	58
Transverse diameter of the frontals at postorbital processes	68
Transverse diameter of muzzle at canine	51
Greatest length of mandible	182
Height of mandible at coronoid process	82

Dentition.—The dentition ($I\frac{3}{3}$ $C\frac{1}{1}$ $P\frac{4}{4}$ $M\frac{3}{3}$) of *Daphœnodon superbus* is completely preserved. The first and second upper incisors are laterally compressed and resemble those of *Daphœnus* more than those of recent forms. $I^{\underline{3}}$, however, displays a rapid approach to the characters found in *Canis*, *i. e.*, it has attained a much larger size and a more nearly caniniform structure. The tooth ($I^{\underline{3}}$) is isolated by diastemata; the one in front being quite short, while the one behind is equal to the greatest transverse diameter of the tooth. As a whole the incisors are proportionally somewhat larger than those of *Daphœnus felinus* and $I^{\underline{3}}$ is distinctly further advanced toward conditions found in *Canis*. As has been stated elsewhere, the canine, though quite robust, is not so large, nor of the shape seen in *Amphicyon giganteus* of Europe, to which genus it was wrongly referred. In the present genus the tooth is of moderately large size, oval in cross-section and recurved quite as in *Canis occidentalis*, though somewhat less compressed than in that species. The base of the tooth and the fang are rounder, which causes a greater swelling on the side of the muzzle than is seen in the latter form.

The molar-premolar teeth have rather blunt cusps. $P^{\underline{1}}$ is single-rooted and

has a simple crown; it is separated from the canine and $P\frac{2}{}$ by short diastemata. The latter tooth is also isolated, but the diastema back of it is very short. This tooth has two roots; its crown is comparatively simple, there being no anterior or posterior basal cusps. $P\frac{3}{}$ is simple-crowned, like the anterior premolar, and otherwise has about the same relative proportions as in *Daphœnus felinus*. Its position in the alveolar border is oblique, which makes it appear of small antero-posterior diameter in the side view of the skull. In $P\frac{4}{}$ (carnassial) a slight change from what is observed in the Oligocene genus has taken place. The deuterocone is slightly reduced in size and is closer to the main body of the tooth than in either *Daphœnus* or any of the allied John Day forms, and in this respect is more like the corresponding tooth in *Amphicyon major* of Europe. The deuterocone is, however, supported by a much heavier root than either in *Amphicyon* or *Canis* and its oblique position in the alveolar border is totally unlike the latter genera. The smaller antero-posterior diameter and otherwise primitive features of the tooth places the genus rather closer to the Oligocene form and removes it further from *Canis*. $M\frac{1}{}$ and $M\frac{2}{}$ are larger than in any of the allied John Day forms (*Temnocyon, Mesocyon, Paradaphænus*) and have also undergone some changes from the corresponding teeth in the Oligocene genus, while $M\frac{3}{}$ is apparently the same. This change of the molars is principally due to the greater development of the postero-internal angle, which gives these teeth a slightly greater antero-posterior diameter internally than is usually seen in the Oligocene species, and the tooth is otherwise apparently intermediate between that of these early forms and *Canis occidentalis*, which has a very prominent, sharp, and crescentic postero-internal tubercle, especially on $M\frac{1}{}$. The development of the postero-internal angle is unusually like what we find in *Amphicyon major* and it is quite curious to find the conical structure of the different tubercles so nearly alike in the two genera. $M\frac{2}{}$ and $M\frac{3}{}$ of the European genus are, however, proportionally larger, the posterior intermediate cusp (metaconule), especially on $M\frac{2}{}$, is more strongly developed and the antero-external cusp (paracone) is the larger, while in *Daphœnodon* para- and metacones are subequal and of the primitive type met with in *Daphœnus;* in fact the tubercles are more depressed than in the latter genus, as is seen by referring to the illustrations, Pl. LXXV. The internal border of the grinding surface of $M\frac{2}{}$ extends slightly below that of the preceding tooth. This character, which is well shown on Pl. LXXIV, may, in part at least, be due to slight displacement. $M\frac{3}{}$ is, as stated, practically a duplication of that tooth in *Daphœnus, i. e.*, a small tooth with transversely oval and very low crown with a very short root, the alveolus which is posteriorly formed by a thin and very delicate border in the maxillary.

The lower incisors are laterally compressed. $I_{\overline{1}}$ is quite small in comparison with that of *Canis*, while $I_{\overline{2}}$ and $I_{\overline{3}}$, though small, are in better proportion. The canine is robust and resembles that of *Canis occidentalis* very closely, the cross-section of the crown being somewhat more regularly oval and less excavated on the antero-internal angle. $P_{\overline{1}}$ is a small single-rooted tooth with the crown extended well forward from the base, the apex being nearly directly over the anterior face of the root. The tooth is isolated by diastemata, of which the one in front of it is the longer. The next three premolars are also well separated in the jaw. $P_{\overline{2}}$ and $P_{\overline{3}}$ have simple conical crowns with larger posterior than anterior bases and their shape and relative diameters are quite similar to those in *Daphœnus*, while $P_{\overline{4}}$ is somewhat enlarged and has a strong posterior cusp and prominent cingulum similar to some species from the Oligocene, *Daphœnus dodgei* Scott and *Temnocyon altigenis* Cope from the John Day formation of Oregon.

In $M_{\overline{1}}$ (carnassial) is observed the greatest change from what appears in the Oligocene form in the direction of the more recent type. It is at once seen that this tooth has increased in its antero-posterior diameter, the metaconid is situated lower down,[9] and the hypoconid is bluntly trenchant and is greatly developed, while the entoconid is rather small. The tooth is not, however, modified into the perfect shearing blade met with in *Canis*, as it still retains to a greater or less extent the conical structure of the tubercles so characteristic of *Daphœnus* and its ancestors, the *Miacidæ*. $M_{\overline{2}}$ is quite large; the trigonid is raised only very slightly above the heel; the proto-, para-, and metaconids are fused into a more or less solid and obtuse mass, the protoconid being the largest of the three, while the paraconid is represented only as a basal heel on the antero-internal angle. The heel is quite large and is occupied principally by an antero-posteriorly placed ridge (hypoconid) which is low and located nearer the external than the internal border. The entoconid is represented by a low and oblique ledge on the postero-internal angle of the crown. $M_{\overline{3}}$ is single-rooted and is reduced to a small oval-shaped crown with a slight elevation on the anterior half, while postero-internally there is a shallow valley produced, to some extent by trituration. The size of the tooth with reference to the one preceding it is proportionally the same as in *Daphœnus felinus* here used for comparison.

[9] It is interesting to note that *Cynodesmus brachypus* from the Miocene of the Laramie Peak locality is apparently further advanced towards the recent dogs in having the premolars larger, $M_{\frac{1}{2}}$ reduced and the lower carnassial of less transverse diameter.

MEASUREMENTS OF DENTITION.

	Mm.
Length of superior premolar series	55
Length of superior molar series	34
Antero-posterior diameter of superior canine at base	13
Transverse diameter of superior canine at base	10
Antero-posterior diameter of P^1	6
Transverse diameter of P^1	5
Antero-posterior diameter of P^2	11
Transverse diameter of P^2	5
Antero-posterior diameter of P^3	13
Transverse diameter of P^3	7
Antero-posterior diameter of P^4	22
Transverse diameter of P^4, anteriorly	11
Antero-posterior diameter of M^1	19
Transverse diameter of M^1	24
Antero-posterior diameter of M^2	13
Transverse diameter of M^2	18
Antero-posterior diameter of M^3	5
Transverse diameter of M^3	8
Length of inferior premolar series	47
Length of inferior molar series	46
Antero-posterior diameter of inferior canine at base	12
Transverse diameter of inferior canine at base	10
Antero-posterior diameter of P_1	6
Transverse diameter of P_1	4
Antero-posterior diameter of P_2	19
Transverse diameter of P_2	5
Antero-posterior diameter of P_3	13
Transverse diameter of P_3	6
Antero-posterior diameter of P_4	16
Transverse diameter of P_4	8
Antero-posterior diameter of M_1	25
Transverse diameter of M_1	11
Antero-posterior diameter of M_2	14
Transverse diameter of M_2	10
Antero-posterior diameter of M_3	9
Transverse diameter of M_3	7

Although there are a number of apparently strong specific characters in the dentition of the second specimen (No. 1589a) found with the type, I refrain from establishing a second species on account of the immaturity of the specimen. In this second specimen the upper and lower premolars are much more crowded in the alveolar border in comparison with those in the type specimen. The upper carnassial has a better developed postero-external cutting ridge (tritocone) and the cusps are generally more trenchant. P_4 is relatively somewhat larger with a higher crown, the metaconid of the lower carnassial slightly smaller and M_3 two-rooted.

The remains indicate an animal of slightly larger size when fully adult (see Figs. 2 and 3).

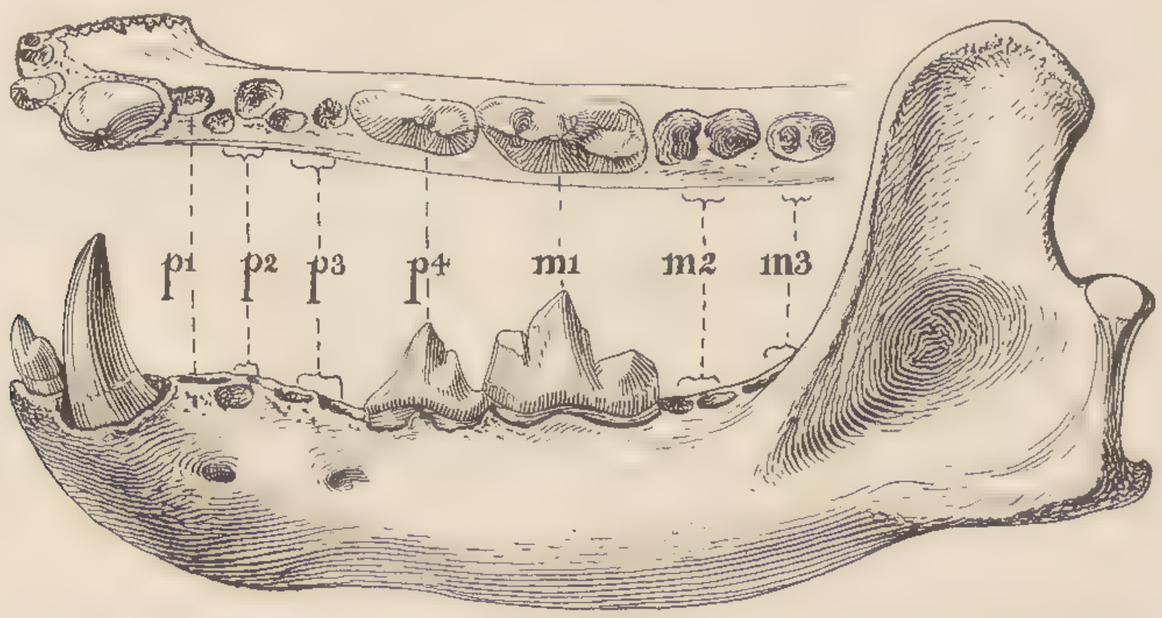


FIG. 3. Lower Jaw of Young Individual of *Daphœnodon superbus*. $\frac{2}{3}$ nat. size. No. 1589a.

In section 17 of Quarry No. 1 was found a fragment of a mandibular ramus with the deciduous sectorial in position and the permanent $p\frac{4}{}$ buried in the jaw. The latter tooth is only partially developed. The different cusps of the deciduous tooth are quite sharp and the heel is of considerable size and completely basin-shaped. The fangs are excessively spread in the antero-posterior direction, due to the constant pressure from below by the permanent tooth, and furnish a sure indication of the juvenility of this tooth. Except for its slightly smaller size, the tooth most nearly resembles that of "*Canis*" *anceps* Scott and is here figured for the purpose of warning the student. The specimen may or may not represent *Daphœnodon superbus*.

FIG. 4. *Daphœnodon superbus?* Fragment of lower jaw of young individual with deciduous sectorial in place and p_4 buried in the jaw (No. 2201). Nat. size.

THE VERTEBRAL COLUMN.

The formula of the vertebral column is as follows: cervicals seven, dorsals thirteen, lumbars seven, sacrals three, and caudals twenty-eight?

With the exception of the missing region of the caudals, already referred to in the introduction, the vertebral column of the type specimen is in excellent preservation.

Atlas.—The atlas is quite long antero-posteriorly. Its large attenuated and wing-like transverse process gives the bone a transverse diameter proportionally equal to that in *Canis*. In general outline the bone is quite similar to that of the latter genus, but there are a number of differences shown on closer examination which

reveal conditions more nearly identical with those found in *Daphœnus*. Thus the posterior exit of the vertebrarterial canal is not superior as in the dogs, but more nearly posterior as in the cats;[10] the anterior cotyles are small; the transverse

FIG. 5. Atlas of *D. superbus*. ½ nat. size. 1, dorsal view; 2, lateral view; 3, ventral view.

diameter of the articulation for the axis is proportionally less in size; and the bone, with the exception of the transverse process, is, as a whole, rather heavier than in *Canis*. The atlanteo-diapophysical notch is deep and as in the dogs is not covered with a bony bridge to form a foramen. This character was observed in *Daphœnus* by Professor Scott,[11] while in some of the genera of the *Miacidæ* (*Oödectes*) this notch was already converted into a foramen.[12] The foramen in the arterial groove, which pierces the wall of the neural arch on the ventral face of the transverse process, is exceedingly small, which is also the case in the atlas of *Daphœnus* here used for comparison. In *Canis* this foramen is of larger size.

FIG. 6. Atlas of *Cynodesmus brachypus* Cope. No. 8140, Cope Collection, Am. Museum Natural History. ½ nat. size.

In the atlas of *Cynodesmus brachypus* the posterior exit of the vertebrarterial canal is more dorsally located (see Fig. 6); its atlantal notch is not nearly so deep and the foramen piercing the neural arch on the ventral face of the transverse process is as large as in *Canis*.

MEASUREMENTS OF ATLAS.

	Mm.
Greatest antero-posterior diameter	52
Greatest transverse diameter	99
Antero-posterior diameter at cotyles	39
Transverse diameter of cotyles anteriorly	51
Transverse diameter of cotyles posteriorly	36

Axis. — In comparison with *Canis* the axis is short and high and according to Professor Scott's description of the axis in *Daphœnus* it appears also to differ from that genus in some important and rather surprising details. Scott says: "The cen-

[10] Wortman, J. L., "Osteology of Patriofelis," Bull. Am. Mus. Nat. Hist., Vol. VI, p. 137, 1894.

[11] "Notes on the Canidæ of the White River Oligocene," Trans. Amer. Philos. Society, Vol. XIX, p. 337, 1894.

[12] Matthew, W. D., "Carnivora and Insectivora of the Bridger Basin," Memoirs Am. Mus. Nat. Hist., Vol. IX, p. 367, 1909.

trum is elongate, narrow, and depressed, with a thin and inconspicuous hypopophysial keel." In *Daphœnodon superbus* the centrum, though somewhat depressed, is short in comparison with that of *Canis* and the hypopophysial keel is more strongly developed than in the latter. The ventral face of the centrum in the present genus is not nearly as concave antero-posteriorly as in the dog, and the ventral keel terminates posteriorly in a broader area, which is extended downward very slightly so as to form of its posterior three-fourths a slight antero-posterior concavity, but there is no prominent tubercle as in *Canis*. The articulation for the atlas is more convex and rises higher upon the sides than in *Canis* and is apparently not materially changed from that in the Oligocene form. The odontoid process also agrees with Professor Scott's description of that in the older form, which he says is "a long, slender, bluntly pointed peg, with a heavy, rounded ridge upon its dorsal surface, which is continued back along the floor of the neural canal." The transverse process is heavier, shorter, and is more nearly parallel to the centrum than in *Canis*, which is also characteristic of *Daphœnus*. On the lower border of the transverse process is developed an inferior branch or costal element (see Fig. 7) which is rather unusual on the axis among the dogs and is not mentioned by Scott in his description of this process in *Daphœnus*. The vertebrarterial canal is apparently slightly further forward than in *Daphœnus*, but it is still further back and slightly longer than in *Canis*. The neural canal is large, as in *Daphœnus*, and does not contract so much towards the hinder end as in *Canis*. The spinous process is a long high keel which is produced into a laterally compressed process anteriorly, rapidly expands posteriorly, and is proportionally lighter than in the cats, *e. g.*, *Felis leo*. The posterior face of the spine is excavated somewhat as in *Felis*, though in a less degree, and forms a different attachment for the cervical muscles than is seen on the convex and rugose surface in *Canis*. According to Scott, the neural spine in *Daphœnus* corresponds practically to the description here given.

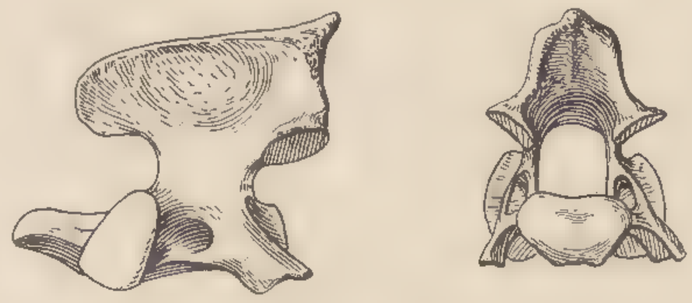


FIG. 7. Lateral and Posterior Views of Axis of *D. superbus*. ½ nat. size.

In *Cynodesmus brachypus* the centrum of the axis is long and narrow and in its general features, including the inferior keel and the odontoid process, answers more nearly to that of *Canis* than to that of *Daphœnus* and *Daphœnodon*, while the neural spine is extremely long and overhanging both anteriorly and posteriorly. The latter process is proportionally longer than that in *Leo*, and tapers more gradually from the base of the postzygapophyses to the free end as in the Eocene creodonts.

MEASUREMENTS OF AXIS.

	Mm.
Antero-posterior diameter of the centrum, odontoid process included	54
Greatest transverse diameter of centrum, anteriorly	36
Greatest transverse diameter of centrum, posteriorly	22
Antero-posterior diameter of spine	53
Transverse diameter across postzygapophyses	34

Third Cervical Vertebra. — The general characters of the third cervical vertebra are similar to those of the same bone in *Canis*, though certain features are rather feline. Thus the inferior branch of the transverse process is strongly developed, the tubercle superior to the postzygapophysis is large and points directly backwards, and the neural spine is considerably developed, while in *Canis* the transverse process is smooth, the tubercle above the postzygapophysis points more upwardly and the neural spine is less developed. The centrum is short and has a strong keel, which terminates posteriorly in a broad area, but does not form a hypopophysial tubercle as in the dogs; the transverse process is shorter and broader, and the vertebrarterial canal is longer.

MEASUREMENTS OF THIRD CERVICAL VERTEBRA.

	Mm.
Antero posterior diameter of centrum	31
Antero-posterior diameter of neural arch including zygapophyses	46
Transverse diameter across transverse processes, posteriorly	52
Transverse diameter of centrum posteriorly	22
Vertical diameter of centrum posteriorly	14

Fourth and Fifth Cervical Vertebræ. — The fourth and fifth cervical vertebræ are heavier than the preceding vertebra. The postero-inferior branch, or costal element of the transverse process, is also more developed; the neural arches are more deeply emarginated in front and behind; the neural spines are higher and the tubercles above the postzygapophyses are smaller. There are otherwise no marked differences between the third, fourth, and fifth cervical vertebræ. In the two latter vertebræ the ventral keel of the centrum does not terminate posteriorly in a tubercle as in *Canis*, but laterally has a broad area with small tubercles, similar to what is observed in *Felis leo*.

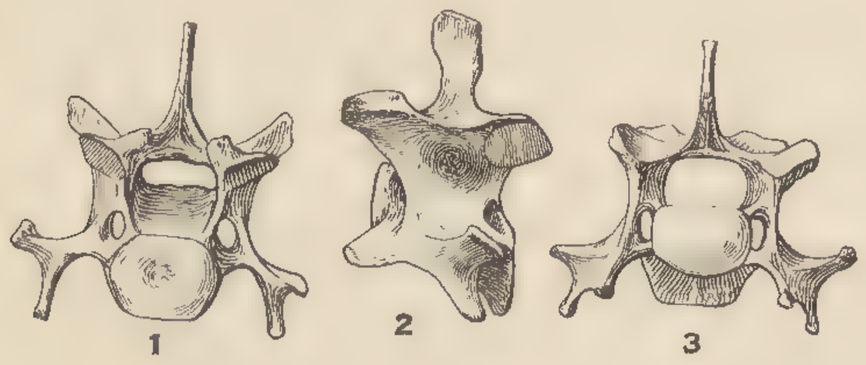


FIG. 8. Fifth Cervical Vertebra of *D. superbus*. ½ nat. size. 1, posterior view; 2, lateral view; 3, anterior view.

MEASUREMENTS OF FOURTH AND FIFTH CERVICAL VERTEBRÆ.

	C. 4 Mm.	C. 5 Mm.
Antero-posterior diameter of centra	31	30
Transverse diameter of centra, posteriorly	22	22
Vertical diameter of centra, posteriorly	15	16
Transverse diameter across transverse processes, posteriorly	55	59
Transverse diameter across prezygapophyses, posteriorly	43	43
Transverse diameter across postzygapophyses	41	39

Sixth Cervical Vertebra. — The sixth cervical vertebra has the faces of the centrum more oblique than in any others of the cervical series, but not more opisthocœlous. The centrum is otherwise depressed and rather broad, as are the centra of all the cervicals. The ventral keel is quite prominent in the anterior region, but fades away to an evenly convex border posteriorly and is quite similar to that in *Canis*. The transverse process is very prominent, as in the latter genus, but the inferior lamella is divided into two parts, a small anterior and a larger posterior portion (see fig. 9). In the thoöids this lamella forms a solid and thin blade, while in the alopecoids it is generally slightly divided. In the cats it is divided in a greater or less degree. The vertebrarterial canal is proportionally longer than in *Canis*. The neural arch is broad, but does not form the connecting ledge between the pre- and postzygapophyses as prominently as in *Canis*; there is no excessory process developed on this connecting ledge as in the latter genus, though it would appear from Professor Scott's description (*l. c.*, p. 338) that these ledges are perhaps more prominent on the arches of the cervical vertebræ in the present genus than in *Daphœnus*.

FIG. 9. Sixth Cervical Vertebra of *D. superbus*. ½ nat. size.

FIG. 10. Cervical Vertebræ of *Cynodesmus brachypus* Cope (No. 8140 Cope Collection, Am. Museum of Natural History). ½ nat. size.

The anterior and posterior emarginations on the neural arches which separate the zygapophyses in front and behind the neural spines of the cervical vertebræ are deeper than in *Canis*; they are not unlike those in *Viverra africana*, and in this respect are similar to what was found by Scott to be the case in the Oligocene genus. The neural spine of the sixth cervical in the type is slightly damaged, but its entire length is represented, and it is shown to be robust and high.

In the sixth cervical vertebra of *Cynodesmus brachypus* the inferior branch of the transverse process is divided, but the anterior portion is much larger proportionally than that in *Daphœnodon*. In all other respects the bone is more nearly like that in *Canis* than *Daphœnodon*. In fact the entire cervical series in *C. brachypus* is strikingly similar to that of the recent form except that the posterior exit of the vertebraterial canal of the atlas is further back, the neural spine of the axis more produced posteriorly, the inferior lamella of the transverse process of the sixth cervical is divided, and the neural spine of the seventh cervical is more robust and higher.

MEASUREMENTS OF SIXTH CERVICAL VERTEBRA.

	Mm.
Antero-posterior diameter of the centrum	29
Transverse diameter of the centrum posteriorly	23
Vertical diameter of the centrum posteriorly	27
Transverse diameter at transverse processes	59
Transverse diameter of prezygapophyses	43
Transverse diameter of postzygapophyses	57

Seventh Cervical Vertebra.—The seventh cervical is characterized by its long and heavy transverse processes and neural spine, which are proportionally quite large when compared with those of *Canis*. From Professor Scott's observation it is quite clear that *Daphœnus* also had high neural spines on the cervical vertebræ, which is generally characteristic of the felines. It is further noticed that the anterior and posterior faces of the neural spine of the seventh cervical in *Daphœnodon* have conspicuous excavations at the base, which are not present in *Canis* and *Felis*, while in *Viverra zivetta* they are represented to a slight extent. These excavations have rough surfaces for muscular attachment, and the one posterior is deeper than the one anterior. The four vertebræ preceding the one under description have similar rough excavations (see Fig. 8) and these excavations also appear in the case of the anterior dorsals. (See Fig. 13.)

FIG. 11. Seventh Cervical Vertebra of *D. superbus*. ½ nat. size.

MEASUREMENTS OF SEVENTH CERVICAL VERTEBRA.

	Mm
Antero-posterior diameter of centrum	27
Transverse diameter of centrum posteriorly	25
Vertical diameter of centrum posteriorly	18
Transverse diameter of transverse processes	67
Transverse diameter of prezygapophyses	43
Transverse diameter of postzygapophyses	43
Height of neural spine	47

First Dorsal Vertebra.—The centrum of the first dorsal is, as in *Daphœnus*, broad and depressed, which seems to be true of the dogs generally. The transverse process is heavier than in *Canis lupus*. The postzygapophyses point forward and outward in a greater degree; their zygapophysial articulations are larger and present a more obliquely concave appearance than in the later genus, while the postzygapophyses are quite similar in every respect. The neural spine is robust and high, but on the whole proportionally lighter than in *Canis*. The excavations on the spine referred to in the description of the preceding vertebra are also continued to the dorsal series, and in his description of *Daphœnus* (*l. c.*, p. 339) Scott speaks of this condition as follows: "the notch between them [prezygapophyses] is very deeply incised, invading the base of the spine, a very different arrangement from that seen in *Canis*."

FIG. 12. First Dorsal of *D. superbus*. ½ nat. size.

MEASUREMENTS OF FIRST DORSAL VERTEBRA.

	Mm.
Antero-posterior diameter of the centrum	25
Transverse diameter of the centrum	29
Vertical diameter of the centrum	16
Transverse diameter across the transverse processes	63
Transverse diameter across prezygapophyses	45
Transverse diameter across postzygapophyses	30
Height of neural spine	60

Second Dorsal Vertebra.—The centrum of the second dorsal is less depressed than that of the first, its anterior face being of more nearly circular outline and quite convex. Ventrally there are two prominent ridges on either side of the median keel, which extend nearly the entire length of the centrum. The transverse process and the zygapophyses are lighter than on the preceding vertebra. The prezygapophyses face inward and slightly upward; at their lower margins they are abruptly concave, due to sharp ridges at their bases which extend diagonally upward and inward, uniting with the anterior border of the neural spine a short distance above the arch. The triangular area on the anterior face of the spine, which is bounded laterally by these ridges, is quite deep and has a rugose surface identi-

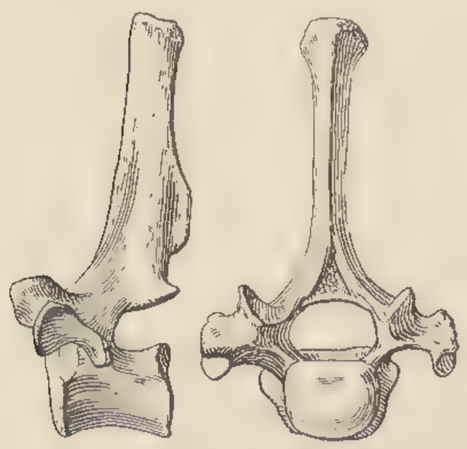


FIG. 13. Lateral and Posterior Views of Second Dorsal of *D. superbus*. ½ nat. size.

cal with that which has been described in the preceding vertebra, and is well shown in the illustration, Fig. 13.

MEASUREMENTS OF SECOND DORSAL VERTEBRA.

	Mm.
Antero-posterior diameter of the centrum	23
Transverse diameter of the centrum, posteriorly	27
Vertical diameter of the centrum, posteriorly	16
Transverse diameter at the transverse processes	50
Transverse diameter at the prezygapophyses	55
Transverse diameter at the postzygapophyses	22
Height of neural spine	57

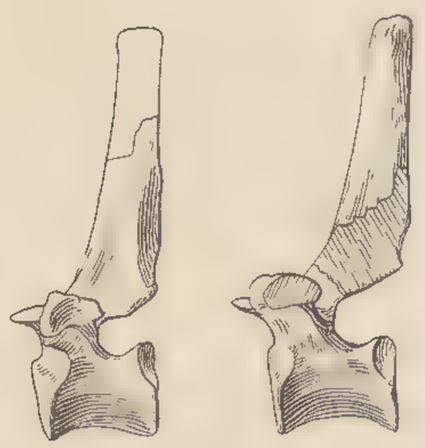


FIG. 14. Lateral Views of Third and Fourth Dorsals of *D. superbus*. ½ nat. size.

Third and Fourth Vertebræ.—The third and fourth dorsals have their centra similar to that of the second. The transverse processes are lighter, the prezygapophyses are less complicated, facing directly upward,and the neural spines are less expanded at the top than in the preceding vertebra; there are otherwise no characters which require a separate description.

MEASUREMENTS OF THIRD AND FOURTH DORSAL VERTEBRÆ.

	D 3. Mm.	D 4. Mm.
Antero-posterior diameter of centra	23	25
Transverse diameter of centra	25	23
Vertical diameter of centra	16	16
Transverse diameter at transverse processes	47	44
Transverse diameter at prezygapophyses	24	21
Transverse diameter at postzygapophyses	20	
Height of neural spine approximately	57	56

Fifth, Sixth, Seventh, Eighth, and Ninth Dorsal Vertebræ.—This series of dorsals are so similar to one another that they do not each require a separate description. The centra are quite uniformly concave on the sides and have a ventral keel more or less indicated, while the individual increase in the antero-posterior diameter from the fifth to the ninth is hardly perceptible. The articular surfaces for the ribs are large and the intervertebral notches are low but of considerable antero-posterior dimensions. The transverse

FIG. 15. Ninth Dorsal of *D. superbus*. ½ nat. size.

processes decrease but very slightly from the fifth to the ninth, the articular surfaces for the ribs are extensive on the free and expanded ends, but the excessory processes on the superior faces, which are so prominent in the recent dogs, are very inconspicuously developed. The neural spines in the whole series are heavy, but gradually reduced in height in proceeding backward, the ninth being quite thin transversely though broad antero-posteriorly.

MEASUREMENTS OF FIFTH AND NINTH DORSAL VERTEBRÆ.

	D. 5 Mm.	D. 9 Mm.
Antero-posterior diameter of centra	24	25
Transverse diameter of centra	24	26
Vertical diameter of centra	16	17
Transverse diameter at transverse processes	50	47
Height of neural spines	60	43

Tenth Dorsal Vertebra.—The centrum of the tenth dorsal vertebra is similar to that of the ninth, with the exception of the absence of facets for the capitulum of the rib. The transverse process is still quite heavy and has a large facet for the tuberculum of the rib, as is well shown in Fig. 16. The prezygapophysis is like that in the preceding vertebra, while the postzygapophysis is placed high and faces downward and outward, similarly to that in the recent dogs. The neural spine, however, is very characteristic in the present genus and different from that in the recent form. In *Canis lupus* the spine is thin transversely, quite broad antero-posteriorly, very low and upright in position—a character which was apparently already established in some of the early tertiary forms (*Miacidæ*).[13] In *Daphœnodon superbus* the neural spine of this vertebra is more backwardly inclined, and, with the exception of the postzygapophysis and the sudden reduction in size, it is like that in the true dorsals. In *Canis latrans* the neural spine of the tenth dorsal is apparently quite similar to the one here described, though much shorter in proportion.

FIG. 16. Tenth Dorsal of *D. superbus*. ½ nat. size.

MEASUREMENTS OF TENTH DORSAL VERTEBRA.

	Mm.
Antero-posterior diameter of centrum	25
Transverse diameter of centrum, posteriorly	25
Vertical diameter of centrum	16
Transverse diameter at transverse processes	47
Height of neural spine, approximately	35

[13] Matthew, W. D., "Carnivora and Insectivora of the Bridger Basin," Memoirs Amer. Mus. Nat. Hist., Vol. IX., p. 367, 1909.

Eleventh Dorsal Vertebra.—The centrum of the eleventh dorsal vertebra is longer and also of slightly greater vertical diameter than is the case in the preceding vertebra and, as in the latter, there are no facets for ribs on the posterior face. The eleventh and twelfth dorsals in the skeleton of *Daphœnus felinus* (No. 492) have no facets on the posterior faces, although there are instead little rounded processes which extend slightly behind the faces of the centra, but which apparently never touched the heads of the ribs, as there are no articular facets noticed on them.

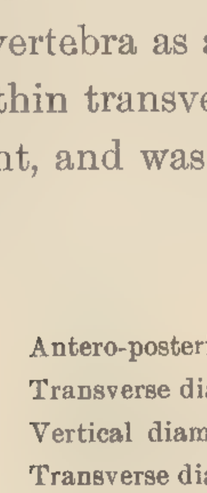


FIG. 17. Eleventh Dorsal of *D. superbus*. ½ nat. size.

The characters of the neural arch, zygapophyses, and spinous process are suddenly changed in this vertebra, and are on the whole more like those of the true lumbars. The bone is injured in the region of the transverse process, but enough is preserved to indicate its rather small size, and it is quite doubtful whether it carried an articular facet for the tuberculum of the rib as in *Canis* and other recent Carnivora. The meta- and anapophysis are more prominent than in *Canis;* in fact the vertebra as a whole is heavier. Judging from the base of the neural spine it was thin transversely and rather broad antero-posteriorly; it did not attain a great height, and was perhaps more or less anticlinal.

MEASUREMENTS OF ELEVENTH DORSAL VERTEBRA.

	Mm.
Antero-posterior diameter of centrum	26
Transverse diameter of centrum	24
Vertical diameter of centrum, approximately	17
Transverse diameter at transverse processes	37
Height of neural spine, approximately	15

Twelfth and Thirteenth Dorsal Vertebræ.—The twelfth and thirteenth dorsal vertebræ increase rapidly in size from the one preceding them. The twelfth is characterized by the practical absence of a transverse process, there being only a trace of a tubercle present near the posterior border of the pedicel immediately above the intervertebral notch. On the thirteenth dorsal is a decided knob-like transverse process which is shifted lower down than on the eleventh. The ventral keel is a heavy rounded ridge and is more prominently developed on the thirteenth than on the last vertebra mentioned. The meta- and anapophyses are seen to be decidedly more robust in the two vertebræ here described

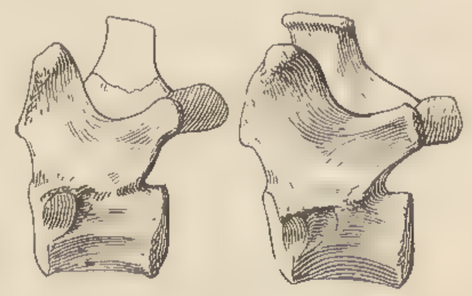


FIG. 18. Twelfth and Thirteenth Dorsal Vertebræ of *D. superbus*. ½ nat. size.

and the zygapophyses and neural spines, especially of the thirteenth dorsal, are typically lumbar in character.

MEASUREMENTS OF TWELFTH AND THIRTEENTH DORSAL VERTEBRÆ.

	D. 12 Mm.	D. 13 Mm.
Antero-posterior diameter of centra	28	29
Transverse diameter of centra posteriorly	26	27
Vertical diameter of centra posteriorly	17	19
Transverse diameter at transverse processes	31	33
Height of neural spine		25

First Lumbar Vertebra. — The first lumbar vertebra is slightly larger than the last dorsal. Besides the absence of facets for ribs it also differs from the latter in having a sharper ventral keel, better developed lateral tubercles on the ventral posterior face of the centrum, larger transverse processes, which are placed lower down, and a slightly heavier neural spine. In *Daphœnus felinus* the lumbar vertebræ have relatively longer and narrower centra, with the ventral keel and lateral posterior tubercles of greater prominence, longer transverse processes, and the neural spines possibly somewhat higher than in the present genus.

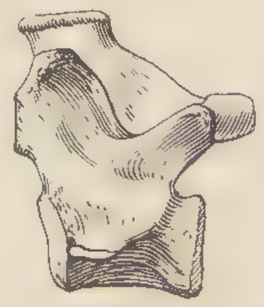


FIG. 19. First Lumbar Vertebra of *D. superbus*. ½ nat. size.

MEASUREMENTS OF FIRST LUMBAR VERTEBRA.

	Mm.
Antero-posterior diameter of centrum	33
Transverse diameter of centrum	27
Vertical diameter of centrum	19
Transverse diameter at transverse processes, approximately	45
Height of neural spine	26

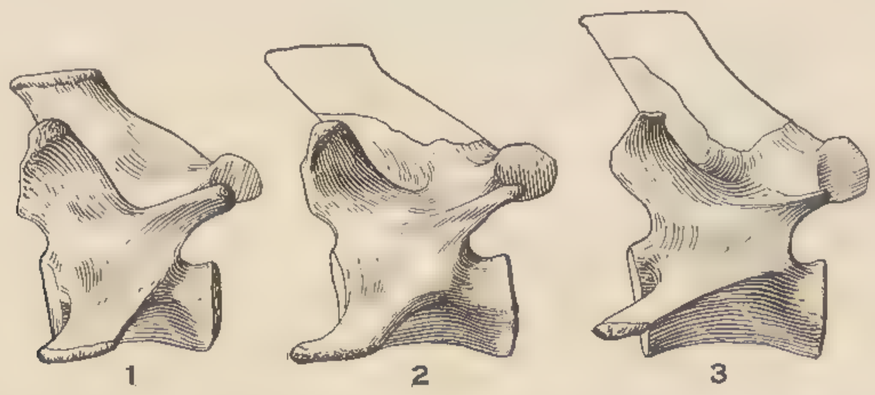


FIG. 20. Lumbar Vertebræ of *D. superbus*. ½ nat. size. 1, second lumbar; 2, third lumbar; 3, fifth lumbar.

Second, Third, Fourth, and Fifth Lumbar Vertebræ. — This series of the lumbars may conveniently be described together. Their centra are broad and heavy, not unlike those in *Canis*, while the transverse processes, though quite heavy and directed forward, are much shorter than in the latter genus. The latter character

is a curious feature of this genus which seems to have departed from *Daphœnus*, *Temnocyon*,[14] and also from the recent canids generally, while, according to observations by Dr. Matthew (*l. c.*, p. 367) upon *Miacis*, its affinity with regard to the short transverse processes would seem to recall the earlier tertiary types. As in *Daphœnus* the metapophyses, anapophyses, and neural spines are proportionally more robust than those in the recent dogs. The meta- and anapophyses are heaviest on the first lumbar and gradually decrease in size backwards, the anapophysis of the fifth lumbar being quite small. Except on the first, second, and seventh lumbars the neural spines are broken off superiorly, but enough remains to ascertain their great antero-posterior diameters, which are not unlike those in canids generally.

MEASUREMENTS OF SECOND AND FIFTH LUMBAR VERTEBRÆ.

	L. 2 Mm.	L. 5 Mm.
Antero-posterior diameter of centra	36	40
Transverse diameter of centra posteriorly	27	29
Vertical diameter of centra posteriorly	19	19
Transverse diameter of transverse processes	50	72
Length of transverse processes from base (posterior) to tip end	14	24
Height of neural spine	18	?

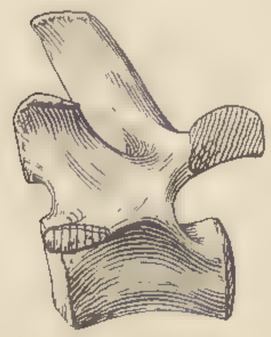


FIG. 21. Sixth Lumbar Vertebra of *D. superbus*. ½ nat. size.

Sixth Lumbar Vertebra.—The sixth lumbar vertebra is characterized by the absence or very rudimentary development of anapophyses, and also by a considerable transverse broadening of the centrum posteriorly. There is otherwise very little difference between this vertebra and the one preceding it.

MEASUREMENTS OF SIXTH LUMBAR VERTEBRA.

	Mm.
Antero-posterior diameter of centrum	40
Transverse diameter of centrum	31
Vertical diameter of centrum	19
Transverse diameter at transverse processes, approximately	84
Height of neural spine, approximately	45

Seventh Lumbar Vertebra.—The centrum of the seventh lumbar vertebra is as usual quite depressed. The transverse diameter of the posterior face is nearly equal to its antero-posterior diameter and the ventral keel and lateral ridges are prominent, especially on the anterior half of the centrum. The transverse process is

[14] Eyerman, J. "The Genus Temnocyon and a New Genus thereof, etc." Amer. Geol., Vol. XVII, pp. 273–274, 1896.

unfortunately not completely preserved; enough remains, however, to determine that it is fully as heavy as in *Canis*, but probably did not attain the length seen in the latter. The pre- and postzygapophyses, especially in the latter, are much expanded in comparison with those of the preceding lumbars, and the neural spine is also quite light, although comparatively heavier than in the recent dogs.

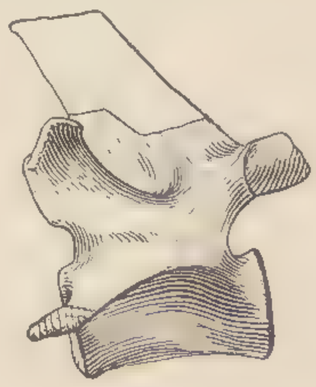


FIG. 22. Seventh Lumbar Vertebra of *D. superbus*. ½ nat. size.

In the type of *Cynodesmus brachypus* the lumbar series (seven) is apparently completely represented. The centra, especially in the anterior part of the series, are somewhat less depressed than in *Daphœnodon*. The transverse processes, though relatively longer than in *Daphœnodon*, are not attenuated to the same degree as in recent dogs. The metapophyses, anapophyses, and neural spines are proportionally lighter than in *Daphœnodon* and on the whole more nearly resemble the lumbar vertebræ of *Canis*.

MEASUREMENTS OF SEVENTH LUMBAR VERTEBRA.

	Mm.
Antero-posterior diameter of centrum	34
Transverse diameter of centrum posteriorly	31
Vertical diameter of centrum posteriorly	18
Transverse diameter at transverse processes, approximately	72
Height of neural spine	33

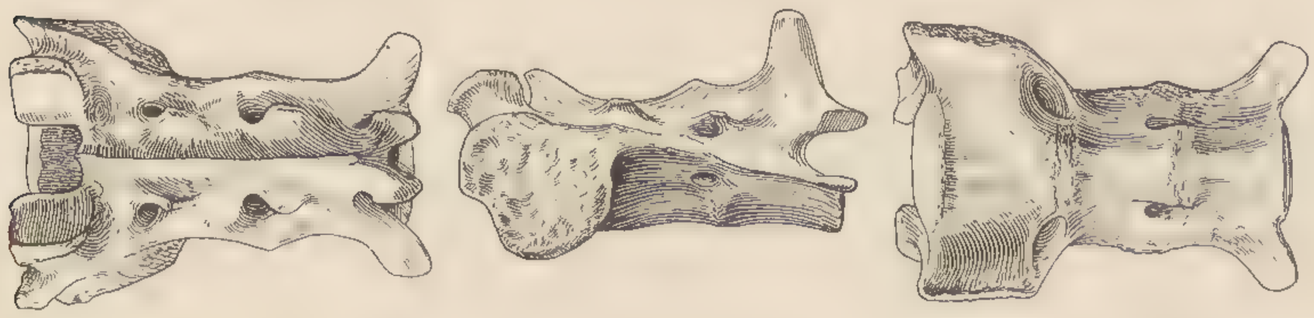


FIG. 23. Dorsal, Lateral, and Ventral Views of Sacrum of *D. superbus*. ½ nat. size.

Sacrum. — The sacrum is greatly developed, and, as usual, it consists of three well coössified vertebræ. In its relative size it is fully equal to that of *Daphœnus* described and figured by Professor Scott (*l. c.*, p. 341, Pl. XX, fig. 14), and is very much larger than in the recent dogs and proportionally somewhat more robust than in the lion or the tiger. The centra are unusually massive and not nearly so depressed as in the recent dogs, but resembling more those of the tiger. The transverse processes however, are, very differently arranged, only the first sacral supporting the ilium by its very heavy pleurapophyses; the second has the transverse process rep-

resented by a comparatively delicate roughened ridge, while the third has a prominent process which extends laterally and slightly back of the posterior face of the centrum. In the recent forms the transverse processes of the sacrum are more strongly developed, the first and second sacrals, especially, taking a more prominent part in the support of the ilium. In comparison with the heavy centra the neural canal is rather small, thus agreeing with what is observed in the Oligocene genus and differing from recent forms. The neural spine of the first sacral is relatively smaller than in the recent dogs or cats, while that of the last sacral is much heavier, the spine on the median vertebra consisting only of a sharp low ridge, which uninterruptedly connects with the spines in front and behind.

In *Cynodesmus brachypus* the sacrum is shorter and broader, the second sacral helps to support the ilium more prominently and the anterior neural spines were apparently proportionally more robust than in *Daphœnodon*. The spinous process on the last sacral in *C. brachypus* however, is, quite prominent, and is more completely separated from the spine in front of it than in either *Daphœnodon* or the recent dogs.

MEASUREMENTS OF SACRUM.

	Mm.
Antero-posterior diameter of centra	77
Greatest transverse diameter across the pleurapophyses	59
Greatest transverse diameter at transverse processes of last sacral	49

Caudal Vertebræ. — The tail is very long and heavy; it has undergone practically no change from that of the Oligocene form and is practically as well developed as in the lion or the tiger. The anterior face of the centrum of the first caudal is more convex and less depressed than the posterior. The transverse process is very heavy and projects well backwards. The pre- and postzygapophyses have perfectly formed articular facets and are well expanded transversely. The neural canal is of moderately large size and the spinous process is quite robust.

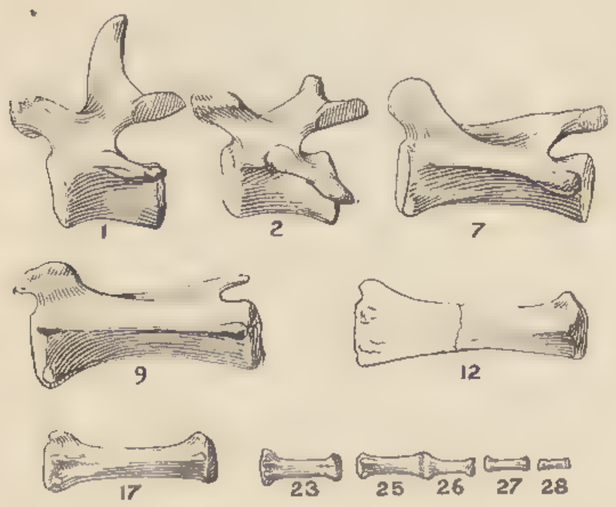


FIG. 24. Caudal Vertebræ of *D. superbus*. ½ nat. size. (1-28 indicate their respective positions in the tail.)

The length of the centra of the succeeding two caudals agrees with that of the first. The transverse process on the second however, is, broader antero-posteriorly than in the first, but the neural spine is very much reduced, while on the third caudal the neural spine is represented only by a low ridge. The centrum of the fourth caudal is four or five millimeters longer than

that of the first, while back of this vertebra the increase in length is more noticeable. The transverse processes are single up to the sixth, and the seventh caudal still bears the pre- and postzygapophyses with perfect articular facets in front and behind, while on the eighth and ninth the postzygapophyses are more or less imperfect, but the neural canal is complete and extends throughout nearly the entire length of the vertebræ. The last mentioned vertebra is the longest in the series which was attached to the sacrum when the specimen was found, but there is reason for believing that the vertebra continued to increase in length up to the eleventh or twelfth caudal. There are seven chevron bones present which were found more or less in position in the series of caudals here described.

At the anterior portion of the tenth caudal the skeleton was exposed and a section of the tail dropped out. As mentioned in the introduction, the natural curve in which the tail undoubtedly was lying would allow room for six or possibly seven vertebræ. Working on this hypothesis the next vertebra which was found in position in the skeleton would be the seventeenth or eighteenth. This vertebra has the pre- and postzygapophysial prominences, anterior transverse processes, and ventral tubercles for chevrons well represented, and the centrum is of considerable length and robustness. The ten succeeding vertebræ gradually decrease in length and robustness, the last being only seven millimeters long.

In the type of *Cynodesmus brachypus* the anterior four caudal vertebræ are present together with various others which represent different parts of the tail. The transverse process on the first is very long and robust, while on the second it is much shorter and indicates a greater decrease backward than is seen in *Daphœnodon.* The centra are less depressed than in the latter genus and approach more closely those in the dogs. It is quite likely that the tail in *C. brachypus* when completely known will be found to be proportionally shorter than in *Daphœnodon superbus.*

MEASUREMENTS OF CAUDAL VERTEBRÆ.

	C. 1 Mm.	C. 2 Mm.	C. 9 Mm.	C. 17 Mm.	C. 28 Mm.
Antero-posterior diameter of centra	23	24	46	35	7
Transverse diameter of centra posteriorly	22	20	16	8	2
Vertical diameter of centra posteriorly	15	14	14	9	2
Transvere diameter at transverse processes	57	67	26	12	

RIBS AND STERNUM.

There are very few ribs represented with the type specimen, while in No. 1589a (the young individual found with the type) they are quite complete. The series as a whole is rather short and stout with much expanded ventral ends. In the ante-

rior region of the thorax the ribs have large capitular and tubercular articulations and rather flat shafts as in *Canis*, while posteriorly they are more cylindrical; the eleventh, twelfth, and thirteenth having no tubercular articulations.

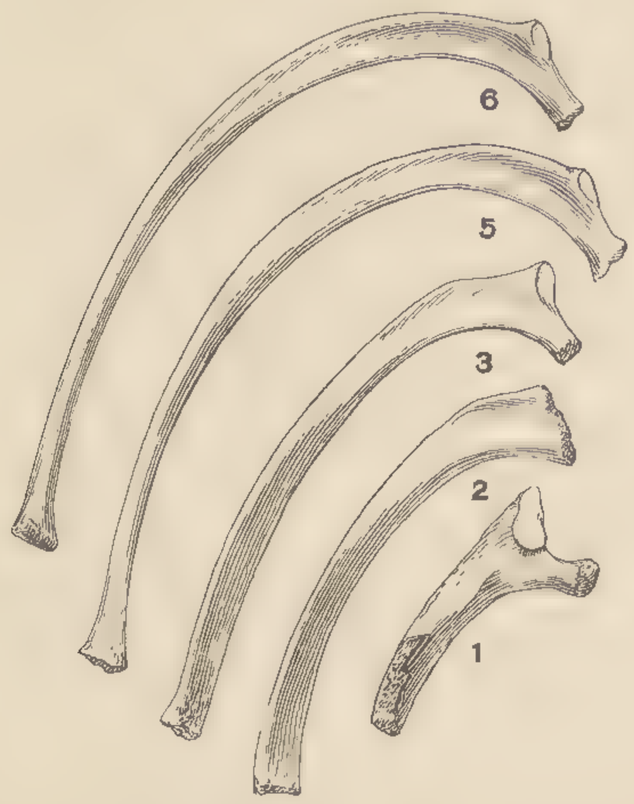


FIG. 25. Ribs of Left Side of *D. superbus*. ½ nat. size. 1, first rib, type No. 1589; 2, second rib No. 1589a; 3, third rib No. 1589a; 5, fifth rib No. 1589a; 6, sixth rib No. 1589a.

Sternum.— The sternum is represented only by the manubrium, which is more nearly like that in the tiger than in the dogs. Thus its size is proportionately large and it is greatly produced in front and much expanded transversely at the attachment for the first pair of ribs. In front of the rib facets the superior face has a subtriangular area which is concave from side to side and also slightly concave antero-posteriorly. In front the bone terminates in an obtuse, laterally compressed process, which projects forward and slightly downward. The ventral face is produced into a heavy rounded antero-posterior ridge, which gives the bone a strong keel-like appearance. The posterior half of the presternum is more angular on cross-section.

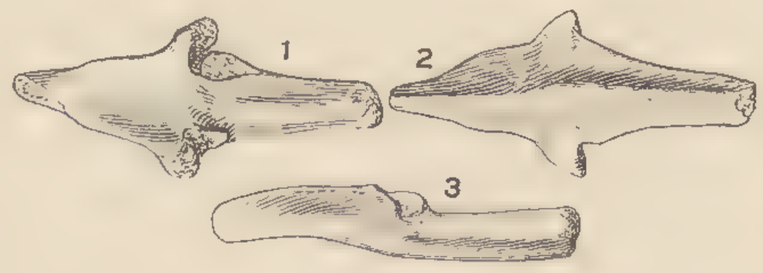


FIG. 26. Presternum of *D. superbus*. ½ nat. size. 1, dorsal view; 2, ventral view; 3, lateral view.

MEASUREMENTS OF PRESTERNUM.

	Mm.
Greatest length	73
Transverse diameter at first rib facets	33
Vertical diameter at first rib facets	13

THE OS PENIS.

The os penis which is so well developed and characteristic in *Daphœnus* is not less so in *Daphœnodon*. With the type and the younger skeleton there was found the anterior portion of an os penis (Fig. 27, 2) which I judge might belong with the young individual. The portion of the shaft present is sub-cylindrical in cross-section, with a sinuous curve and deeply grooved near the bisected end.

In the material belonging to a skeleton of *Daphœnodon* in Amherst College, Massachusetts, now in the Carnegie Museum,[15] there is an os penis of very large size, and also different in its general shape from that described above (see Fig. 27, 1).

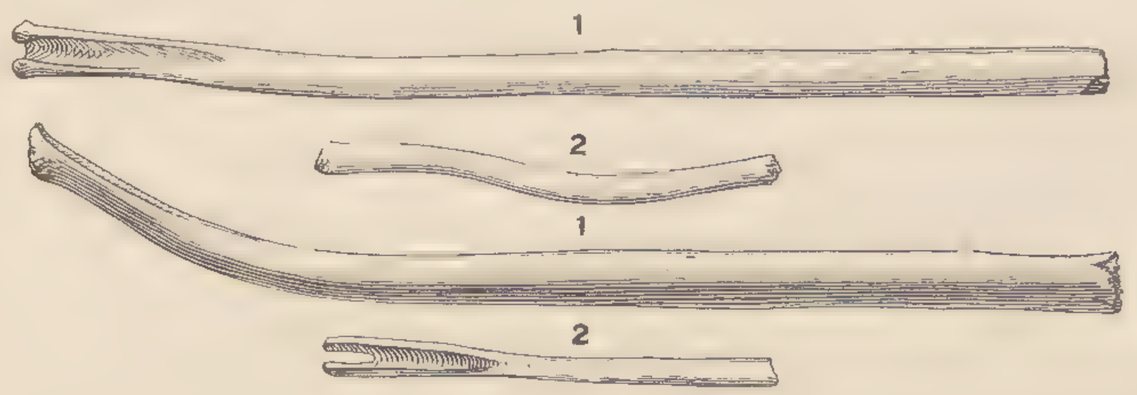


FIG. 27. Os Penis of *D. superbus*. ½ nat. size. 1, superior and lateral views of os penis, Amherst specimen; 2, superior and lateral views of os penis with skeleton No. 1589a, Car. Mus. Cat. Vert. Foss.

Thus its shaft is more elliptical in cross-section, especially toward the posterior end, and it has a less complex curvature at the anterior end. It is, however, deeply grooved near the anterior end as in the smaller specimen, though not bisected, but suddenly expanded to a round spout with many small tubercles on the anterior border. How much longer this bone was is rather difficult to say, but it would seem that it is broken off immediately in front of the rugose surface for the attachments of muscles to the pubes. Whether the larger bone represents the fully adult stage of development or pertains to another species cannot now be fully determined. If, on the other hand, the two different bones represent fully adult forms there is apparently a great range of variation of this bone in this genus.

THE FORE LIMB.

(Plates LXXVIII–LXXX.)

Scapula (Plate LXXVIII). The scapula is well preserved and completely represented in the type specimen as well as the younger specimen found with it. This important bone of the fore limb displays a number of rather surprising features and probably sheds considerable light on the characters of the scapula in *Daphœnus*, which is not yet known. The bone as a whole reveals a curious combination of the features of the scapula of the tiger and the bear, and shows less similarity to that of the Canidæ. As in the tiger, the bone is elongated, with sub-equal pre- and post-scapular fossæ, the coracoid border is suddenly expanded and again contracted

[15] On further excavation by the writer in the quarry where Prof. Loomis of Amherst found the skeleton, there were found various parts which belong to the Amherst specimen and will be forwarded to that institution.

before the suprascapular border is reached, and the acromion process on the spine is well developed, while the postscapular fossa is unequally divided by the prominent and sharp glenoid border, identically as in the bears. In the fox the scapula has a small area developed for the teres major muscle at the superior portion of the glenoid border, but it is quite small in comparison with that in the present genus, in which the scapula as a whole is proportionally broader transversely. The spine is high and terminates in an overhanging acromion, which, however, does not project below the glenoid cavity. Judging from the heavy acromion process there was undoubtedly a clavicle of perhaps considerable development. The glenoid cavity is not so large proportionally as in the large cats, and in this respect is rather more like that in *Canis*. The coracoid process also has about the same proportionate development as in *Canis* and is relatively much shorter than in the tiger.

Professor Scott states (*l. c.*, p. 381) that in *Cynodictis* "the coracoid process is unusually large . . ." that the "prominent acromion descends below the level of the glenoid cavity . . ." and that in general character the scapula "is rather viverine or raccoon-like than canine," which is not true of the scapula in *Daphœnodon*.

In *Temnocyon ferox*, according to Eyerman's description[16] "the greatest vertical length [of the scapula] is from the coracoid to the posterior upper edge and not along the spine, as in *C. familiaris*. This is not the case in the present genus, nor is the spine "falling short of the supra-scapular border," as in the John Day genus, but in this respect it is more nearly like the dogs.

It is interesting to note that the area for the teres major muscle on the upper part of the glenoid border of the scapula in *Hoplophoneus* is also quite large, and is quite similar to that in *Daphœnodon*.

MEASUREMENTS OF SCAPULA.

	Mm.
Greatest height from glenoid cavity to suprascapular border	167
Greatest antero-posterior diameter	104
Antero-posterior diameter of glenoid cavity, including the coracoid process	39
Transverse diameter of glenoid cavity	23

Humerus (Plate LXXIX).—The humerus has apparently changed very little in its general characters from that of the Eocene forms. The slight shortening of the bone and the less developed supinator ridge, together with the somewhat greater development of the internal epicondyle in the present form are, the only noteworthy differences from those in the Oligocene genus *Daphœnus*. The tendency to a reduction of the supinator ridge in *Daphœnodon* is a distinct step from the early

[16] Eyerman, J. The American Geologist, Vol. XVII, p. 274, 1896.

types[17] toward the recent canids, while the bone on the whole tenaciously retains features met with in the early progenitors; *viz.*, the presence of the entepicondylar foramen, the heavy deltoid ridge which extends well down on the shaft, and many other minor details.

In comparing the humerus with that of the tiger the similarity is surprisingly close, the deltoid crest of the recent form being proportionally even less developed, while the distal trochlea is transversely somewhat broader in proportion. The

FIG. 28. Radius and Ulna of *D. superbus*. ½ nat. size.

humerus of *Amphicyon major* of Europe has also a greater transverse diameter distally and the supinator ridge is more rounded and heavier than in the genus under description.

MEASUREMENTS OF HUMERUS.

	Mm.
Greatest length	211
Antero-posterior diameter of head	52
Transverse diameter of head at tuberosities	44
Greatest transverse diameter of distal end	55
Greatest transverse diameter of distal trochlea	34
Greatest antero-posterior diameter of distal end	32

Radius and Ulna (Plate LXXIX). — The radius is proportionally longer and the humerus shorter in *Daphœnodon* than in *Daphœnus*. It is also observed that the shaft of the bone in the former genus has a less sinuous curvature than in the latter; in other respects there are only minor details of difference in the two genera, and the feline characters are practically as prominently shown in the later as in the earlier form, *i. e.*, the inner margin of the head overhangs the shaft as in the cats, the articular surface with the lesser sigmoid cavity of the ulna extends well around on the internal side of the head, and the tubercle for the biceps muscle is very prominent, while the distal end is quite broad transversely and displays well marked tendinal grooves, which, however, are not as well developed as those in the tiger.

The radius in *Amphicyon major* is also quite cat-like, though the tendinal grooves on the inner angle of the distal end are apparently less developed than in *Daphœnodon*.

[17] Wortman, J. L., "Study of Eocene Mammalia," etc., American Journal of Science, Vols. XI–XIV, p. 348, Fig 9, p. 438, 1902.

The olecranon process of the ulna is very short, truncated, and more inwardly produced than in the Oligocene genus. The tendinal sulcus, though well defined and wide, is not so deep as in *Canis lupus*, and consequently much less developed than in the cats. The principal feature of the greater sigmoid notch is its heavy coronoid process, which character is feline rather than canine. The shaft is very heavy and not much curved. The tuberosity for the flexor profundus digitorum muscle on the external border of the shaft is very heavy, as is well shown in Figs. 5 and 6, Pl. LXXIX. Distally the shaft is more trihedral in cross-section due to the sharp ridge which separates the internal and posterior surfaces as in the tiger.

The articulation for the radius on the distal end is a heavy rounded knob much as in the large cats and entirely unlike that in the dogs. The styloid process extends well down and has a decided constriction above the articulation for the cuneiform.

In *Cynodesmus brachypus* both ulnæ are represented. The olecranon process is short and truncated, the tendinal groove is deep as in *Canis*, but the coronoid process is larger in proportion than in the recent dogs, as is also the shaft. The distal end, however, lacks the heavy and broad development of the rounded tubercle which articulates with the radius and is so conspicuous in the genus under description. The feature of this reduction of the ulna in *C. brachypus* is apparently a decided step towards conditions found in *Canis*.

MEASUREMENTS OF RADIUS AND ULNA.

	Mm.
Radius, greatest length	184
Radius, antero-posterior diameter of proximal end	16
Radius, transverse diameter of proximal end	23
Radius, transverse diameter of shaft medially	15
Radius, antero-posterior diameter of shaft medially	12
Radius, greatest antero-posterior diameter of distal end	23
Radius, greatest transverse diameter of distal end	34
Ulna, greatest length	223
Ulna, antero-posterior diameter at coronoid process	32
Ulna, transverse diameter at coronoid process	25
Ulna, transverse diameter of distal end at tubercle	20
Ulna, antero-posterior diameter of distal end at tubercle	11

The Manus (Pl. LXXX).—With the exception of the trapezoid the manus of the type specimen is quite completely represented. As the forefoot was found more or less disarticulated the respective positions of the phalanges as determined by the writer may be somewhat conjectural; their positions are, however, sufficiently correct for a general description.

In comparing the scapho-lunar bone with that of *Daphœnus felinus* it is found

that the similarity is remarkably close. The dorsal face of the bone in the present genus has a less vertical diameter than in the Oligocene form, which is due to the fact that the articulation for the radius is carried further downward on the anterior face than in the older type, in fact lower than in the lion and tiger, consequently far removed from conditions in the recent dogs, in which the dorsal face of the scapho-lunar is very large, the bone being much higher throughout.

The articular facet for the radius also extends far downwards on the palmar face near the ulnar angle, as in the lion and tiger, which indicates that there was even more power of flexure between these two bones (radius and scapho-lunar) in the present genus than in *Daphœnus*, and is a condition strikingly similar to what is seen in the large cats. The radio-palmar process is well developed, but has not the vertical diameter seen in *Canis*, and is more nearly like that in the cats. It is, however, more distinctly separated, by a constriction, from the main body of the bone than in the felines, which is due to the greater development of the palmar face of the scapho-lunar in the latter. The ulnar face has no facet for the cuneiform, which is identical with that in *Daphœnus*, in which the cuneiform and scapho-lunar did not come in touch with one another sufficiently to establish facets. Distally there are well defined facets for the unciform, magnum, trapezoid, and trapezium respectively. The facet for the unciform is deeply excavated as in *Daphœnus*, while that for the magnum is extended downward somewhat less near the dorsal border, the beak of the lunar being less produced downward in the present genus. The facet for the trapezoid is a large, irregularly shaped, and obliquely placed surface, indicating a trapezoid of considerable size. The facet for the trapezium is located on the extreme radial angle, but is poorly demarcated from the facet for the trapezoid.

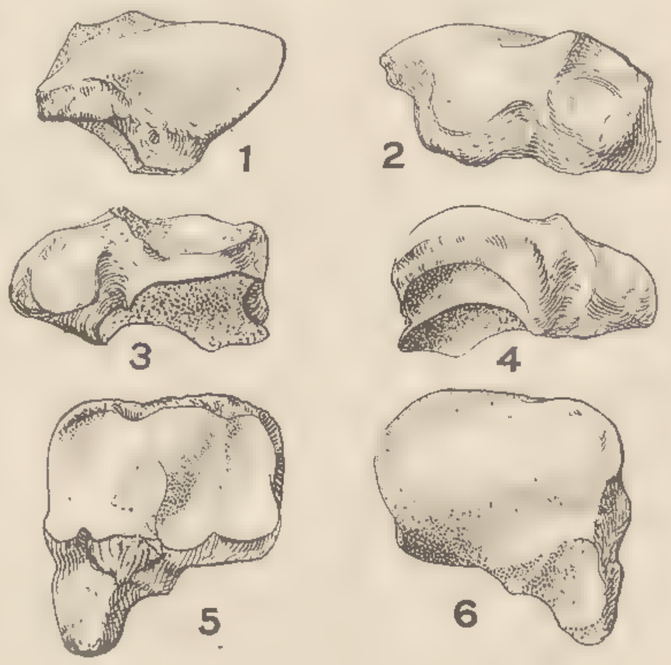


FIG. 29. Scapho-lunar (left sides) of *D .superbus*. Nat. size. 1, dorsal view; 2, palmar view; 3, radial view; 4, ulnar view; 5, inferior view; 6, superior view.

MEASUREMENTS OF SCAPHO-LUNAR.

	Mm.
Greatest antero-posterior diameter, including the radio-palmar process	29
Greatest transverse diameter	29
Greatest vertical diameter near dorsal face	19

Cuneiform.—As in *Daphœnus* the cuneiform is broad laterally, much depressed in the vertical direction, and has a large process which occupies the dorso-ulnar

face of the bone, and furnishes muscular attachment for Mc.V, but does not articulate with the latter as in the dogs. The facets for the ulna and pisiform on the proximal face are subequal in size and are separated by a prominent ridge, the former being more concave antero-posteriorly than the latter. In the dogs the facet for the ulna is different, being more sinuously curved, with an antero-posterior cavity on the ulnar angle and an antero-posterior convexity on the proximo-dorsal angle of the bone. The distal face is taken up by a large facet which is concave in all directions and articulates with the unciform. The bone as a whole is not unlike the cuneiform of the tiger.

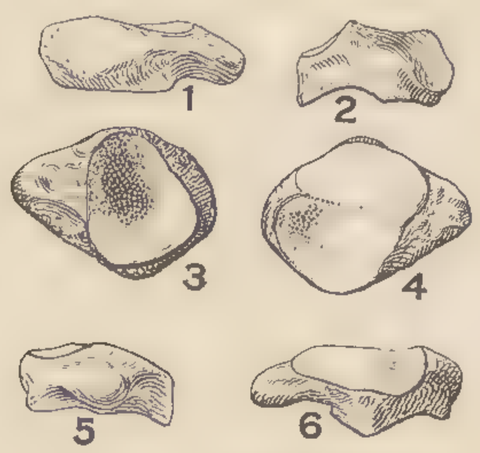


FIG. 30. Cuneiform (left side) of *D. superbus*. Nat. size. 1, dorso-ulnar view; 2, dorsal view; 3, inferior view; 4, superior view; 5, palmar view; 6, palmo-radial view.

MEASUREMENTS OF CUNEIFORM.

	Mm.
Greatest antero-posterior diameter	14
Greatest transverse diameter	20
Greatest vertical diameter of dorsal face	8

Pisiform.—In its general proportions the pisiform is quite robust; it is proportionally slightly heavier than in the tiger, but has a relatively shorter shaft. The articulations for the ulna and cuneiform are subequal in size and thus quite unlike the corresponding surfaces in *Canis*, in which the articulation for the cuneiform is much the larger of the two. As stated above the shaft is short and heavy and terminates in an expanded and truncated free end with the vertical diameter greater than the transverse.

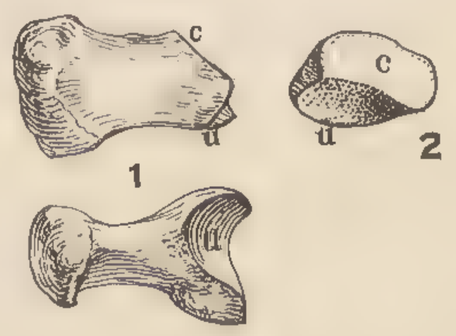


FIG. 31. Pisiform (left side) of *D. superbus*. Nat. size. 1, ulnar and superior views; 2, view of articular facets of cuneiform and ulna; *c*, *u*, cuneiform and ulna facets, respectively.

MEASUREMENTS OF PISIFORM.

	Mm.
Greatest diameter	23
Antero-posterior diameter of articular facets	14
Vertical diameter at articular facets	9
Vertical diameter at free end	14

Trapezium.—The trapezium is of moderately large size. Its dorsal or dorso-radial face is considerably exposed (when viewed from in front), and its general outlines are pentagonal, while on the palmar or postero-ulnar angle there is a heavy

process for attachment of muscles. On the ulnar face is a large facet for the trapezoid, which extends well back, covering the base of the palmar process, referred to above. On the proximal radial angle there are well formed facets for the scapholunar; the one on the radial angle is scarcely separable from the one on the palmar process. Distally there is a large obliquely placed facet for Mc. I which is concave from before backwards.

FIG. 32. Trapezium (right side) of *D. superbus*. Nat. size. 1, dorsal view; 2, radial view; 3, superior view; 4, posterior view; 5, ulnar view; 6, inferior view.

MEASUREMENTS OF TRAPEZIUM.

	Mm.
Greatest antero-posterior diameter	12
Greatest transverse diameter	7
Greatest vertical diameter	10

Trapezoid.— The trapezoid is not known, but judging from the space in the carpus when the trapezium is placed in position it would seem that the trapezoid is larger than the trapezium which is the reverse of what is seen in *Daphœnus*, studied by Mr. Hatcher (*l. c.*, p. 86) and compared by the present writer.

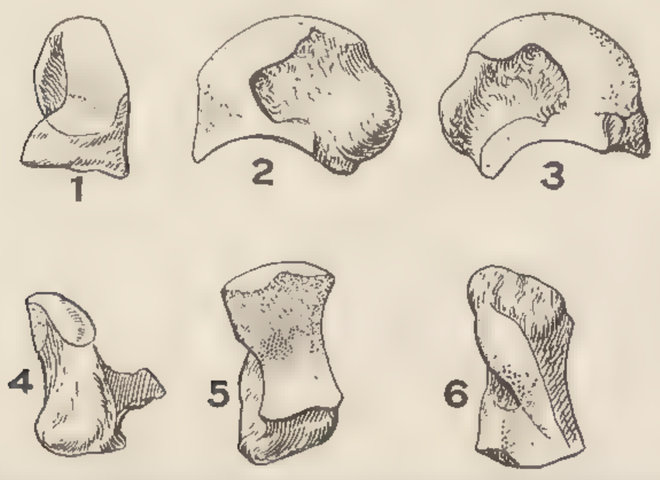


FIG. 33. Magnum (left side) of *D. superbus*. Nat. size. 1, dorsal view; 2, ulnar view; 3, radial view; 4, palmar view; 5, inferior view; 6, superior view.

Magnum.—The magnum has a small dorsal face, but is in general a much larger bone than is indicated by this surface. The dorso-radial angle has a small facet for the trapezoid and this region of the bone is much depressed, while the radial face has a great vertical diameter, due to the sharp ridge which extends upward, articulating radially with the scapho-lunar, and on the ulnar face with the unciform. In *Canis* the ulnar face has a large dorsal and a smaller palmar facet for the unciform; the two facets being separated by a deep groove, while in *Daphœnodon* the facet is uninterrupted and surrounds an excavated area in the middle and posterior portions of the ulnar face. The radial face of the magnum is also deeply excavated. The palmar tuberosity is of considerable vertical diameter, while transversely it is compressed. Distally the bone is occupied by two facets, the larger for

Mc. III and the smaller for Mc. IV. In *Daphœnus* the latter facets are divided in about the same proportions as in the present genus.

MEASUREMENTS OF MAGNUM.

	Mm.
Greatest antero-posterior diameter	20
Transverse diameter of dorsal face	11
Greatest vertical diameter	16

Unciform. — The facet for the cuneiform does not extend so far down on the ulnar angle as is the case in *Daphœnus*, otherwise I cannot see any difference in the unciform in the two genera. On the dorsal face the bone has a transverse excavation and lacks the heavy convex rugosity for muscular attachments seen in the tiger, nor is the palmar tuberosity so well developed; otherwise the bones in the two forms are not greatly dissimilar. From *Canis* the unciform in *Daphœnodon* is at once distinguished by the lateral position of the facet for the cuneiform, the latter facet being more nearly superior on the bones in the true dogs. The radial face is deeply excavated by a sulcus which corresponds to the one described on the ulnar face of the magnum. Around this sulcus is a large continuous, although irregularly shaped, facet for the magnum, which is altogether different from the four separated facets for the magnum in *Canis*. Immediately above the facet for the magnum there is a second facet, which articulates with the scapho-lunar. The anterior portion of this continues into the facet for the magnum in an imperceptible manner, while further back there is a decided ridge separating the two facets. Distally the bone is entirely taken up by the large facets for Mc. IV and V.

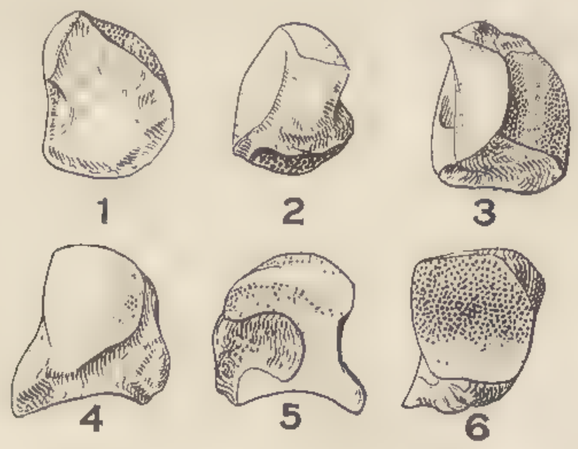


FIG. 34. Unciform (left side) of *D. superbus*. Nat. size. 1, dorsal view; 2, palmar view; 3, superior view; 4, ulnar view; 5, radial view; 6, inferior view.

MEASUREMENTS OF UNCIFORM.

	Mm
Greatest antero-posterior diameter	16
Greatest transverse diameter dorsally	13
Greatest vertical diameter	17

Metacarpal I. — In their general characters the metacarpals are feline rather than canine. The first metacarpal is of approximately the actual length of that in an adult specimen of *Canis lupus*, but it is heavier, its proximal end is more expanded,

and the articulation for the trapezium is broader. In comparative size the bone is very little smaller than in *Daphœnus* and consequently much heavier and longer than in *Canis*. On the ulnar face the rugosity for the ligamentary attachment to Mc. II is quite prominent and the tuberosity on the radial side of the head is as large proportionally as in recent cats, though the bone as a whole however, is, lighter and longer than Mc. I of the pollex in the latter. The distal end has a well formed facet which is separated palmarly by a prominent keel. The shaft is slightly curved, so that the distal end points a little in the ulnar direction.

FIG. 35. Dorsal and Radial Views of Left Metacarpal I of *D. superbus*. Nat. size.

MEASUREMENTS OF METACARPAL I.

	Mm.
Greatest length	32
Greatest antero-posterior diameter of head	10
Greatest transverse diameter of head	11

Metacarpal II. — While the actual length of the first metacarpal is equal to that in *Canis* the second, third, fourth, and fifth are much shorter. This gives a characteristically low and broad appearance to the manus, as in *Meles* or perhaps even more similar to that in *Arctictis*. Thus the second and fifth are of subequal length and are considerably shorter than the third and fourth. The head of Mc. II has the antero-posterior diameter much greater than the transverse, which is due to the comparatively small extent in the ulnar direction of the flange which carries the facet for Mc. III. In the cats this flange is very prominent on Mc. II and III, and forms a more completely interlocking condition of the metacarpals than is seen in the present genus and in the recent dogs generally. The shaft is subcylindrical in cross-section and strongly arched in the dorsal direction. The distal end is suddenly expanded and the trochlea is more cat- than dog-like.

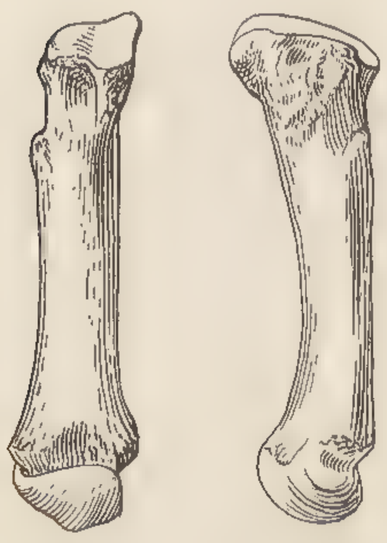


FIG. 36. Dorsal and Radial Views of Left Metacarpal II of *D. superbus*. Nat. size.

MEASUREMENTS OF METACARPAL II.

	Mm.
Greatest length	51
Greatest antero-posterior diameter of head	16
Greatest transverse diameter of head	16

Metacarpal III. — The third metacarpal is slightly longer than the fourth and is consequently the longest in the series. The proximal articulations of this metacarpal as well as all the others are so placed that when articulated the distal ends spread very much more than in the recent dogs. This is also true of the metacarpals in *Daphœnus*. As in the latter genus the dorsal face of the proximal end has a rugose excavation for tendinal attachments, while that area in *Canis* is raised higher up and in place of the excavation there is a considerable eminence. On Mc. III in *Cynodesmus brachypus* this eminence is also well developed. The shape of the different facets of the proximal end are identical with those in *Daphœnus; i. e.*, the facet for the magnum is narrow and deep, that for Mc. II larger and more oblique

FIG. 37. Dorsal and Radial Views of Right Metacarpal III of *D. superbus*. Nat. size.

FIG. 38. Dorsal and Radial Views of Right Metacarpal IV of *D. superbus*. Nat. size.

than in *Canis*, and the facet for Mc. IV larger and more angular near the proximal border. As in Mc. II the shaft is round and arched forward. The distal trochlea is narrower than in the dogs and the dorsal portion is more spherical, while the carina is very prominent.

MEASUREMENTS OF METACARPAL III.

	Mm.
Greatest length	62
Greatest antero-posterior diameter of head	14
Greatest transverse diameter of head	11

Metacarpal IV. — The general features of the head of Mc. IV are not unlike those of the third. The shaft, in fully adult forms however, is, characterized by the prominent rugosity for tendinal attachment on the ulnar angle, while in young individuals it is less noticeable. The shaft is arched in the dorsal direction and the distal end is similar to that of Mc. III.

MEASUREMENTS OF METACARPAL IV.

	Mm.
Greatest length	60
Greatest antero-posterior diameter of head	15
Greatest transverse diameter of head	12

Metacarpal V.—The fifth metacarpal is as heavy as the fourth, but it is shorter, as has been stated before. The proximal end is much expanded, especially in the ulnar direction, which is due to the heavy and rough tuberosity for the attachment of ligaments and muscles. The articulation for the unciform is regularly convex from before backward, the transverse diameter of the palmar area being greater than that near the dorsal face. In *Daphœnus* this articulation is proportionally broader, but the ulnar face of the head is not as prominently developed as in the genus under consideration (see Fig. 39). The dorsal face of the shaft faces to the ulnar side of the manus as well as forward, and the shaft is arched forward in approximately the same proportion as that of Mc. I. The distal end is expanded and points slightly in the radial direction when the bone is in position in the manus. The articulation for the proximal phalanx is similar to those on the metacarpals described above, except that the facet on the ulnar side of the palmar carina is placed higher up and is of larger size than the one on the radial side.

FIG. 39. Dorsal and Radial Views of Left Metacarpal V of *D. superbus*. Nat. size.

MEASUREMENTS OF METACARPAL V.

	Mm.
Greatest length	47
Greatest antero-posterior diameter of head	13
Greatest transverse diameter of head	13

Phalanges.—The proximal phalanges are proportionally somewhat shorter than in the Oligocene genus, otherwise they bear a close similarity in every respect. They are broad, depressed, strongly arched in the dorsal direction, comparatively gently convex dorsally, and rather flat on the plantar faces. The proximal ends are deeply pitted for the distal ends of the metacarpals and the tubercles for ligamentary attachments are very prominent. The distal trochlea is well formed, but is confined almost entirely to the plantar face.

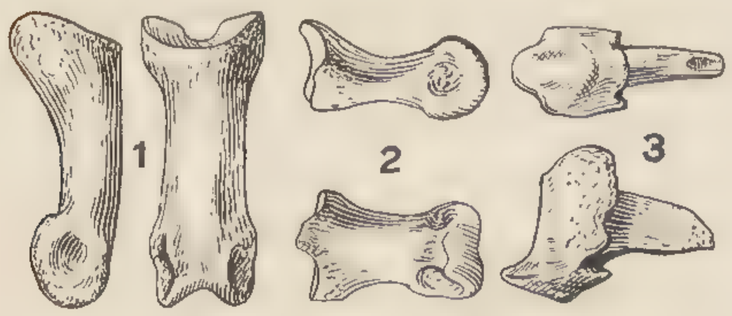


FIG. 40. Phalanges of Digit V (left forefoot) of *D. superbus*. Nat. size. 1, dorsal and radial views of first phalanx; 2, dorsal and radial views of second phalanx; 3, plantar and radial views of terminal phalanx.

The phalanges of the second row are also proportionally shorter than those in the older genus, but display the same curious depression and asymmetrical outlines. Perhaps the most curious feature of these phalanges are their articulations with the terminal phalanges. In the dogs these articulations are decidedly concave from side to side and convex from the dorsal to the plantar faces, while in the present form they are very much less concave in the plantar region and inclined to be convex from side to side at the dorsal faces, like those in the cats.

The ungual phalanges are high, not very long, and compressed laterally. There is a plainly marked groove on the plantar faces near the distal ends of the claw-plates. The latter rise to a sharp ridge dorsally and are of slightly greater transverse diameter on the plantar faces. Proximally the claw-plate is surrounded by a heavy hood, which terminates palmarly in a heavy mass together with the subungual process. The latter extends well back under the distal articulation of the middle phalanx, when articulated with the latter, and supported a strong tendon of the flexor profundus digitorum. Dorsally the hood does not project backward so as to overhang the articulation for the median phalanx as in the cats, but the hood in this region is nevertheless of considerable size and has apparently a rugose area for the attachment of some retractal ligaments. The articulation for the median phalanx is biconcave as in the felines.

After a careful study, there does not seem to be any reason to doubt that this animal had some power of retracting its claws, and in this respect it is identical with *Daphœnus*.

In *Amphicyon major* Mc. III? is proportionally short, the shaft is more greatly arched dorsally, the palmar tuberosity is heavier and the distal trochlea is more hemispherical on the dorsal face than in *Daphœnodon*, which altogether gives even a more feline look to the manus, so far as we know it, in the European species. In *Cynodesmus brachypus* the only bones present which represent the manus are the magnum and Mc. III. The former is decidedly more canine in character than the corresponding bone in *Daphœnodon*, being less depressed in front, having the ascending ridge, which articulates with the scapho-lunar, of much less vertical and greater transverse diameter, and the distal articulation more sharply notched on the radial border. Mc. III in *Cynodesmus* is shorter and lighter than in *Canis latrans*, but the bone is otherwise quite like the latter, especially the proximal end, while its length is about 12 mm. shorter than in *Daphœnodon* and also considerably lighter. A second phalanx, which undoubtedly belongs with the type of *Cynodesmus brachypus*, is quite depressed, but its distal trochlea is concave from side to side and convex from in front backward, as in *Canis*.

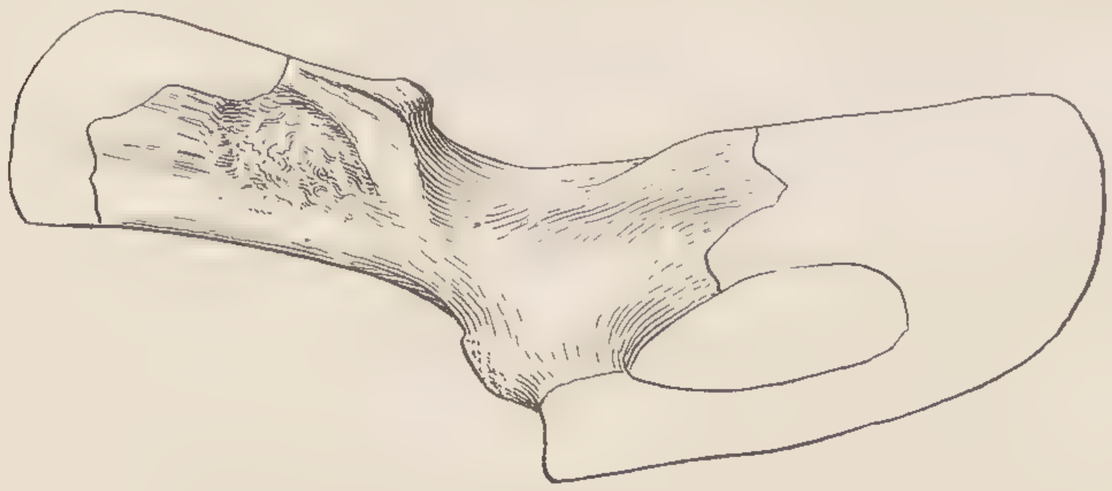


FIG. 41. Internal View of Right Half of Pelvis of *D. superbus*. ½ nat. size.

THE HIND LIMB.

(Plate LXXVIII and Plates LXXXI–II.)

The pelvis of the type is represented by the greater part of the ilium, while the ischium and pubes are represented only by the portions surrounding the acetabulum. In a larger specimen of *Daphœnodon* which belongs to the Amherst College the innominate bone is more nearly complete (see Pl. LXXVIII), but the posterior portion of the ischium is also lacking in this specimen.

In comparing the pelvis with Professor Scott's description of that in *Daphœnus* (*l. c.*, pp. 349–350) it is evident that the similarity in the two genera is quite close. As in the Oligocene genus the gluteal surface of the ilium is divided by a prominent longitudinal ridge, unlike that in recent dogs, or cats where the surface is more evenly concave. The ilium is less expanded at the supra-iliac border than in *Canis*, but probably somewhat more so in comparison with that in *Daphœnus*. The ilium, as a whole, is relatively broader than in the tiger or lion, and is not unlike that in *Viverra zivetta*, as was also observed by Professor Scott in his study of *Daphœnus*. The attachment for the sacrum is quite heavy and is situated well back. The ischial border and the great sacro-sciatic notch is short. The iliac surface is not well defined on account of the short pubic border; the ilio-pectineal eminence however, is, well developed. The acetabular border is very prominent and terminates in a large tubercle at the anterior border of the acetabulum. The latter is of moderate size and depth, the center of the floor being occupied by a large depressed and roughened area, which indicates the attachments of a large cushion of fat as well as the ligamentum teres of the femur. The cotyloid notch is quite broad and excavates the ischium deeply.

As in *Daphœnus* the ischium is long in proportion to that in the recent dogs and even longer proportionally than in the tiger or lion; the obturator foramen consequently has a more oblong outline than in the above mentioned genera and the pelvis as a whole has a greater length.

In *Cynodesmus brachypus* the pelvis is practically complete and again displays characters which are entirely unlike those in *Daphœnodon* and are more like those in the recent canids. The ilium, while not as much expanded at the supra-iliac border as in *Canis*, has a tendency to become more generally concave on the external face, the attachment for the sacrum is more anterior, and the ischium and pubes are decidedly shorter than in the genus under description.

MEASUREMENTS OF PELVIS.

	Mm.
From supra-iliac border to acetabulum, approximately	105
Width of ilium at posterior inferior spine	41
Width of ilium at great sacro-sciatic notch	30
Antero-posterior diameter of acetabulum	28
Vertical diameter of acetabulum	25

Femur (Pl. LXXXI). — The femur of the type is not represented except by surface fragments which may or may not belong to this individual. The younger specimen (No. 1589a) which was found with the type has the shafts of both femora with the proximal ends lost and the distal ends slipped off at the epiphysial sutures (see fig. 42). A third and larger specimen, which belongs to Amherst College, has the femur well preserved. This complete femur will here be used in connection with the description of the type and the material of the younger individual in the Carnegie Museum (see Pl. LXXXI, figs. 1 and 2).

FIG. 42. Dorsal and Fibular Views of Left Femur of Young Individual No. 1589a. ½ nat. size.

The length of the femur cannot be accurately ascertained, but I judge that it is approximately equal to that in an adult specimen of *Canis lupus*. The head is rather small and hemispherical, and the neck is moderately long. The pit for the ligamentum teres is deep and located on the posterior half of the head nearer the inferior than the superior border. When the bone is held in position the head is directed upward and inward in approximately the same proportion as is the case in the recent dogs, and as is also the case in *Daphœnus*. The transverse bridge from the head to the great trochanter is quite heavy on its posterior face, which causes the digital fossa to

appear quite narrow transversely and crowded over to the fibular side of the posterior face. The fossa is not very deep and is partly surrounded by the great trochanter. The latter is not as prominent as in *Canis*, which may be due to individual variation, as I find in the Amherst specimen that the digital fossa and greater trochanter are more nearly of the proportionate size seen in the recent form. The lesser trochanter is prominent and located on the posterior face near the tibial angle as in *Canis*, while in the Amherst specimen it is situated more directly posteriorly. These differences may be due to individual or possibly to specific variations. The third trochanter is not present; while in *Daphœnus* it is apparently represented, though small; in fact Mr. Hatcher in his description [18] did not regard this eminence as being the third trochanter, but in his illustration (*l. c.*, Pl. XIX, fig. 1) he faithfully indicates the tubercle as it appears on the specimen. Dr. Eyerman definitely states that *Daphœnus* has a third trochanter,[19] while Professor Scott [20] did not have material of this genus sufficiently complete to fully demonstrate its presence or absence. The shaft of the young individual referred to above is rather slender, which is due to the immaturity of the animal and must not be regarded as an established character. The shaft of the Amherst specimen is long, slender, arched forward, and has a very prominent and rugose ridge on the fibular angle, which extends nearly throughout the entire length of the shaft, as in the lion. The linea aspera is also well defined.. In No. 1589a the lower portion of the shaft broadens more gradually toward the distal end than is the case in the Amherst specimen, which again may be due to the immaturity of the specimen in the Carnegie Museum. The distal end of the latter has slipped off, as stated above, and as also indicated in the accompanying figure (fig. 42). The condyles in No. 1589a are moderately expanded laterally and posteriorly, which is a feline rather than canine character, while in the Amherst specimen the condyles are well extended back of the vertical line of the shaft, as in *Canis*. These variations may possibly be due to the differences in age of the two specimens. The rotular trochlea is no wider in proportion than in *Canis*, but is somewhat shorter. The intercondylar notch is quite deeply excavated and slightly oblique in position.

Patella. — This bone is not very well represented in the material of the Carnegie Museum. One patella which was found among the surface fragments is proportionately narrower and thicker than that bone in *Daphœnus* and, though larger, is quite similar to that in *Canis*.

[18] "Oligocene Canidæ," Memoirs Carnegie Museum, Vol. I, pp. 88–89, 1902.

[19] American Geologist, Vol. XIII, p. 279, 1896.

[20] Trans. Amer. Philos. Society, Vol. XIX, p. 350, 1898.

Tibia (Pl. LXXXI). — The tibia is represented by the distal ends and the greater portions of the shaft of the right and left, but the proximal ends were unfortunately broken off and lost. The shaft is rather heavy and was apparently quite short. The cnemial crest extends well down and the shaft immediately below this crest becomes triangular in cross-section, with the acute apex of the triangle directed forward. The areas for the different muscles are well defined by distinctly marked ridges, the one on the posterior face which separates the flexor longus digitorum from the flexor longus hallucis being especially prominent. On the distal end the groove for the tendon of the tibialus posticus is well developed, and the internal malleolus is very large as in *Daphœnus*. The astragalar articulation is not so deep as in the recent dogs; it is also more oblique, and does not have the transverse sulcus which interrupts these facets in *Canis*. On the fibular face is a well formed facet for the distal end of the fibula.

MEASUREMENTS OF TIBIA.

	Mm.
Greatest length, approximately	200
Antero-posterior diameter of shaft at lower end of cnemial crest	25
Transverse diameter of shaft at lower end of cnemial crest	17
Greatest antero-posterior diameter of distal end	19
Greatest transverse diameter of distal end	34

Fibula (Pl. LXXXI). —As in the tibia the proximal end of the fibula is also broken off and lost. In proportion the shaft is somewhat more slender than is the case in *Daphœnus*, and has a double curvature; its proximal portion sweeping toward the shaft of the tibia, while more distally it again curves outward and presents a rather short arch before meeting the articular facet for the tibia. As on the latter bone the surfaces for the different muscles are well defined by prominent ridges. The distal end is much expanded. The groove for the peroneus longus is well defined, as is also that for the peroneus brevis and tertius. The two grooves are separated by a prominent tubercle (outer malleolus) similar to that in the lion and quite unlike that in *Canis* where the groove for the peroneus brevis and tertius is very much less developed and the malleolus enlarged. On the tibial face there is a large round facet for the astragalus, which is gently convex in all directions. Immediately above this large facet for the astragalus is a smaller facet for the tibia, which is plane and fits perfectly against a corresponding facet on the external face of the tibia.

MEASUREMENT OF FIBULA.

	Mm.
Greatest length, approximately	190
Antero-posterior diameter of distal end	19
Transverse diameter of distal end	10

Pes (Pl. LXXXII). — The right hind foot of the type was found almost completely articulated. Consequently there is practically no doubt as to the true position of each bone in the pes.

Astragalus. — While the main features of the astragalus are in general quite similar to those in *Daphœnus felinus* there are some detailed differences which are of considerable importance, and which mark the transition from the conditions found in the older type to the more modified structures in the recent forms. It is seen that the articular trochlea for the tibia is more perfectly grooved in the present genus than in *Daphœnus*, the internal and external condyles being more nearly subequal, as in *Canis*. The articulation of the tibial face of the internal condyle, however, is, widely interrupted by a broad vertical sulcus, which is not present in the recent form, nor does it entirely bisect this articulation on the astragalus of *Daphœnus*, while in the tiger there is a similar broad area on the inner side of the internal condyle. The neck is relatively shorter, though constricted as in *Daphœnus*, which is due to the laterally expanded head, as in the cats. The head is inclined sharply inward and on the distal face is a large facet for the navicular, which is convex in all directions. The calcaneal facets are separated by a deep, narrow groove, and are subequal in size, the external being more oblique and less strongly concave than in *Canis*. In the latter genus there is a minute articular facet for the calcaneum on the fibular face of the head. In the present genus this small facet is also present, but instead of articulating with the distal end of the calcaneum, as in the dogs, it comes in contact with the dorso-tibial angle of the cuboid, as in *Daphœnus felinus*.

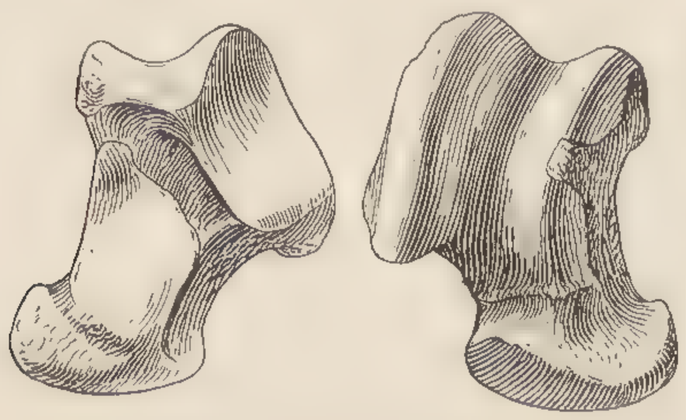


FIG. 43. Anterior and Posterior Views of Astragalus of *D. superbus*. Nat. size.

MEASUREMENTS OF ASTRAGALUS.

	Mm.
Greatest height	38
Transverse diameter of trochlea	21
Transverse diameter of head	21
Antero-posterior diameter of head	12

Calcaneum. — On comparing the calcaneum with that of *Daphœnus felinus* there is very little difference detected except in size. The palmar face of the tuber calcis is more concave antero-posteriorly on its upper portion and slopes more gradually toward the distal end than in the Oligocene genus, which is due to a

greater developed eminence on the lower half of the palmar face in *Daphœnodon.* The free end of the tuber is suddenly expanded, especially laterally, and there is a well defined groove for the tendon of Achilles, as in *Daphœnus* and the recent dogs and cats generally. There is on the outer angle of the dorsal border a long and rugose groove, which, however, is not so deep as that in the Oligocene genus. This groove is also quite conspicuous in the recent lion, while in *Canis* it is entirely wanting. The articular facets for the astragalus are separated as usual by the groove for the interosseous ligament, the external facet being quite oblique and more gently convex antero-posteriorly than in *Canis,* while the sustentaculum is more prominent, the internal facet being slightly concave infero-superiorly and carried well over the superior edge, not unlike what is seen in *Canis.* The greater process of the calcaneum is much abbreviated, so that the head of the astragalus extends well below the distal end, as in *Daphœnus,* also observed by Mr. Hatcher (*l. c.,* p. 91). The peroneal tubercle is well developed, causing the fibular face of the bone to be quite concave supero-inferiorly. The distal end has a large facet for the cuboid, which is gently concave in all directions and pear-shaped in its general outline.

FIG. 44. Anterior and Fibular Views of Calcaneum of *D. superbus.* Nat. size.

The astragalus and calcaneum of *Amphicyon major* are represented in our collection by accurate casts, which display well marked differences from the present genus. In the first place the astragalus in the European form is broader and shorter in proportion; secondly, the head is more sessile, due to the shorter neck; thirdly, the sulcus which separates the articular facet for the tibia on the tibial face of the inner condyle in *Daphœnodon* is absent in *Amphicyon;* and fourthly, the external articular facet for the calcaneum is less concave supero-inferiorly than in the American form.

The tuber of the calcaneum in *Amphicyon* is proportionally shorter, and the palmar border is much heavier than the dorsal, while in *Daphœnodon* the two borders are subequal in thickness, as is also the case in *Daphœnus.* In the European form there is no well defined groove for the tendon of Achilles and the free end of the tuber calcis is much enlarged, as in the bears. The sustentaculum is prominent, as in *Daphœnodon,* but the greater process of the calcaneum is more abbreviated.

MEASUREMENTS OF CALCANEUM.

	Mm.
Greatest length	67
Greatest transverse diameter	33
Length of tuber from sustentaculum to free end	40

Navicular.—The navicular differs from that of *Daphœnus* by having a proportionally greater antero-posterior diameter, which is due almost entirely to the development of the palmar border in the Miocene genus. The tuberosity on the tibial face is also fully as prominent as in the Oligocene form, entirely unlike that in *Canis*, and is not dissimilar to what is found in the recent tiger or lion. The palmar face is, as stated, greatly produced, and formed into a large tuberosity, which, however, is not reduced transversely by the deep notches on the tibial and fibular sides as in *Canis*, but presents a more nearly perfect triangular outline of the entire bone when viewed from above or below. On the fibular face are two small facets, one palmar and the other dorsal. The one located dorsally is sometimes wanting, but in the type it is faintly indicated and touches the lower portion of the facet on the proximal dorsal angle of the cuboid when extreme rotation takes place, while the palmar facet articulates with a corresponding facet on the proximal palmar angle of the cuboid. The facet for the head of the astragalus is concave in the usual manner, while the facet for the entocuneiform is quite large and is not crowded posteriorly in the same degree as in *Canis* or *Felis*.

FIG. 45. Navicular (right side) of *D. superbus*. Nat. size. 1, dorsal view; 2, superior view; 3, fibular view; 4, plantar view; 5, inferior view; 6, tibial view.

MEASUREMENTS OF NAVICULAR.

	Mm.
Greatest antero-posterior diameter	21
Greatest transverse diameter	24
Greatest vertical diameter	11

Entocuneiform.—The entocuneiform, though of considerably smaller size proportionally than in *Daphœnus*, is still of large size, and occupies a more dorsal position in the tarsus than in recent forms. The bone is high, laterally compressed, having the transverse diameter greater on the plantar side than on the dorsal side, and possesses a large plantar hook, which causes the articulation for Mt. I to be

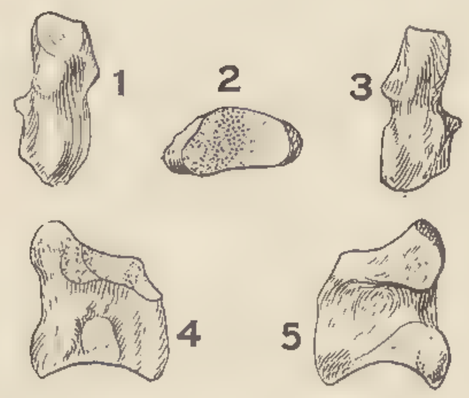


FIG. 46. Entocuneiform (right side) of *D. superbus*. Nat. size. 1, dorsal view; 2, inferior view; 3, plantar view; 4, fibular view; 5, tibial view.

quite concave in the fore-and-aft direction. The proximal articulation for the navicular ascends rapidly in the plantar region, due to a heavy process on the posterior face which points upward and backward. On the fibular face are two facets, a large one proximally for the mesocuneiform and a smaller one distally, which articulates with Mt. II.

MEASUREMENTS OF ENTOCUNEIFORM.

	Mm.
Greatest antero-posterior diameter	13
Greatest transverse diameter	7
Greatest vertical diameter	16

Mesocuneiform. — The mesocuneiform has relatively a greater antero-posterior and a lesser transverse diameter, especially of the distal face, than is the case in *Daphœnus*. Consequently the bone, which is triangular in outline when viewed from below, has a longer apex directed backward than is seen in the Oligocene genus. The facet for the navicular is slightly less oblique than in *Daphœnus*, but has the same antero-posterior concavity. On the tibial face there is a large facet for the entocuneiform which is located on the upper portion of the bone and is concave antero-posteriorly. On the fibular face, near the proximal angle, is a facet for the entocuneiform which extends throughout the entire fibular face, antero-posteriorly, but is of small vertical diameter and corresponds to a facet on the tibial face of the ectocuneiform. Distally the bone is taken up by the facet for Mt. II.

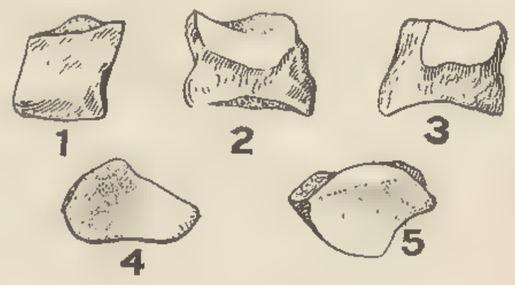


FIG. 47. Mesocuneiform (right side) of *D. superbus*. Nat. size. 1, dorsal view; 2, fibular view; 3, tibial view; 4, inferior view; 5, superior view.

MEASUREMENTS OF MESOCUNEIFORM.

	Mm.
Greatest antero-posterior diameter	13
Greatest transverse diameter	9
Greatest vertical diameter	9

Ectocuneiform. — When the ectocuneiform is compared with that of *Daphœnus* it is at once seen that this bone in *Daphœnodon* has not increased in size in the

same ratio as the entocuneiform has decreased. Both meso- and ectocuneiforms are therefore of approximately the same proportionate size as in the Oligocene form. The dorsal face has a more perfect diamond-shaped appearance than in *Canis* or *Felis*, which is due chiefly to the greater obliquity of the proximal and distal articular facets in *Daphœnodon*. The facet for the navicular on the proximal face is especially oblique, due to a prominent ascending process on the fibular angle. This process has a large facet for the cuboid on its fibular face, and near the distal end there are two minute facets for Mt. IV, one dorsal and the other palmar. The tibial face has three facets, one proximally for the mesocuneiform referred to above, and two distally for Mt. II. The distal face is more oblique and also more concave antero-posteriorly than in the recent forms, while the plantar process is reduced in size and is canine rather than feline in its general characters.

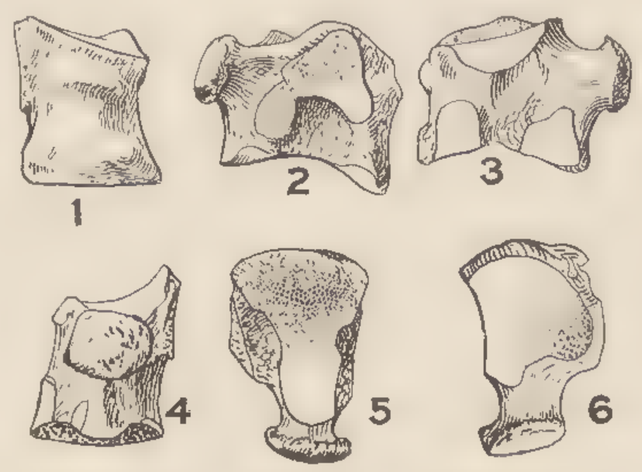


FIG. 48. Ectocuneiform (right side) of *D. superbus*. Nat. size. 1, dorsal view; 2, fibular view; 3, tibial view; 4, plantar view; 5, inferior view; 6, superior view.

MEASUREMENTS OF ECTOCUNEIFORM.

	Mm.
Greatest antero-posterior diameter	21
Greatest transverse diameter	12
Greatest vertical diameter	18

Cuboid. — In comparison the cuboid is of a slightly greater transverse and less vertical diameter than that of *Daphœnus*. Otherwise there are no striking differences in this bone in the two genera. The dorsal face is slightly concave in the proximo-distal direction, while on the fibular plantar face is found the deeply excavated groove for the peroneus longus tendon. Above this groove is a large tuberosity which forms a solid, broad, oblique ridge extending from the proximo-fibular to the distal tibial angle, and not separated by a vertical sulcus as in *Canis*. Superior to this ridge the plantar face is taken up by a large, rugose, excavated area for ligamentous insertions. The fibular face is nearly plane and has three artic-

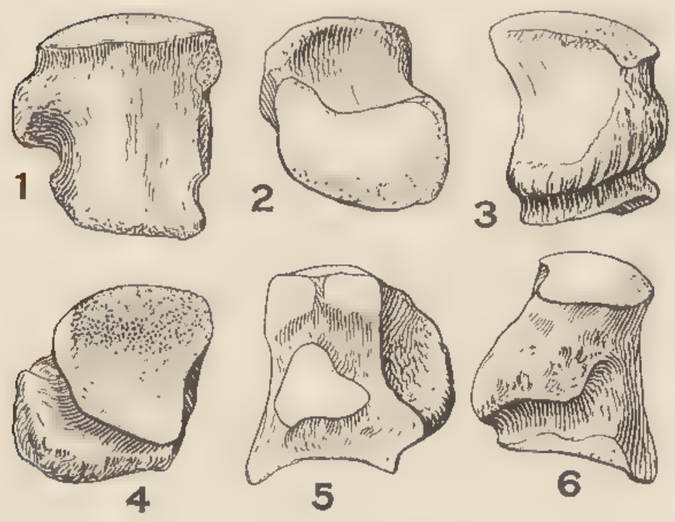


FIG. 49. Cuboid (right side) of *D. superbus*. Nat. size. 1, dorsal view; 2, superior view; 3, plantar view; 4, inferior view; 5, tibial view; 6, fibular view.

ulations; the two proximal ones are small indistinct facets which articulate, one with the head of the astragalus and the other (near the plantar surface) with the navicular. This curious feature of articulations in the tarsal bones is quite unusual and is also found in *Daphœnus* and to a less degree in *Hoplophoneus*, as Mr. Hatcher observed in his study ("The Oligocene Canidæ," p. 91). In the middle region of the tibial face is the third facet, which is of considerable size; it is triangular in outline and articulates with the ectocuneiform. Proximally the cuboid has a large surface for the calcaneum, which is convex in all directions in a greater degree than in *Canis* or *Felis* and even more than in *Hoplophoneus*, though not nearly so oblique as in the latter. Distally there is one large facet for metacarpals IV and V, which is concave antero-posteriorly and also slightly concave laterally, the extreme fibular border being slightly recurved upward to accommodate the lateral portion of the proximal facet of Mt. V.

MEASUREMENTS OF CUBOID.

	Mm.
Greatest antero-posterior diameter	20
Greatest transverse diameter	17
Greatest vertical diameter	21

Metatarsal I. — The first metatarsal has the appearance of being shorter than that of *Daphœnus* when placed in position in the pes, but it is in reality of very nearly the same proportionate length, this shortened appearance being chiefly due to the proportionally less vertical diameter of the entocuneiform in the Miocene genus. These bones (Mt. II) in the two genera are very similar in every respect. As in *Daphœnus* the head is much expanded both antero-posteriorly and transversely, with two prominently developed and rugose tubercles on the plantar face, one on the tibial and t e other on the fibular angle. The facet for the ectocuneiform is quite large and is convex antero-posteriorly, but is slightly more oblique than that of the Oligocene genus, so that the digit points more inward when the pes is articulated. The shaft is of good proportionate size and is arched forward.

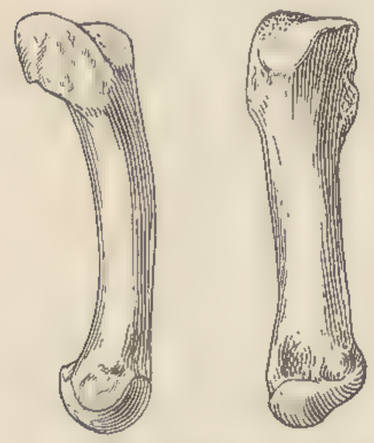


FIG. 50. Fibular and Dorsal Views of Right Metatarsal I of *D. superbus*. Nat. size.

The distal trochlea is hemispherical on the dorsal face and on the plantar face it is divided by a strong keel. With the exception of the reduction of the entocuneiform and the position of the metatarsal there is no great change of the first digit of the pes from that of the Oligocene form, the digit on the whole being more greatly developed than in recent dogs or cats, and more resembling that of *Viverra zivetta*.

MEASUREMENTS OF METATARSAL I.

	Mm.
Greatest length	42
Antero-posterior diameter of head	11
Transverse diameter of head	11
Transverse diameter of distal trochlea	9

Metatarsal II. — As in *Daphœnus* the articular facet for the mesocuneiform on the head of Mt. II is oblique, slightly concave antero-posteriorly, and rises to a high and sharp angle along the fibular border. The fibular side has two large facets for the ectocuneiform, thus the head of Mt. II extends above those on Mt. I and III when articulated in the foot. The plantar tuberosity is of considerable size and is located on the fibular angle. Between the plantar tuberosity and the dorsal face there is on the tibial face an excavated and rough surface, against which lies the head of Mt. I, but there is no true articular facet for the latter. The shaft is much shorter and lighter than in the corresponding bones in *Canis* or *Felis* and is in proportion to the rest of the limb perhaps more nearly like that of the bears. Distally the bone is expanded transversely, the dorsal face of the trochlea being spheroidal and the plantar face divided by a prominent carina as in the metacarpals.

FIG. 51. Dorsal and Fibular Views of Right Metatarsal II of *D. superbus*. Nat. size.

MEASUREMENTS OF METATARSAL II.

	Mm
Greatest length	59
Antero-posterior diameter of head	16
Transverse diameter of head	10
Transverse diameter of distal end	13

Metatarsal III. — As was observed by Professor Scott in his study of *Daphœnus* (*l. c.*,p. 356) the relative proportion of Mt. III is greater than in *Dinictis, Hoplophoneus* or the viverines. It is also considerably longer proportionally than Mt. II in *Canis*, while actually the bone is much shorter in the genus under description. The head has a large antero-posterior diameter, the plantar tuberosity being quite large both transversely and vertically, as in *Canis*. The articular facet for the ectocuneiform is of large size; it is quite oblique in position and is convex both antero-posteriorly and transversely. On the tibial face the head is deeply excavated, but there is no articular facet for Mt. II, except a slight area on the extreme tibial angle

FIG. 52. Fibular and Dorsal Views of Right Metatarsal III of *D. superbus*. Nat. size.

of the plantar tuberosity. On the fibular face there are two facets for Mt. IV, which are separated by a deep sulcus. The dorsal one is located on the posterior face of the flange produced from the dorsal portion of the head, and extends in the fibular direction so as tooverlap Mt. IV, causing a strongly interlocking condition of these bones, as in the carnivora generally. The facet back of the sulcus is on the plantar tuberosity and articulates with a corresponding facet on the plantar tibial angle of Mt. IV. The shaft is quite heavy, considerably arched in the dorsal direction, and oval in cross-section. The distal end is similar to that on Mt. II, but has a more symmetrical trochlea.

MEASUREMENTS OF METATARSAL III.

	Mm.
Greatest length	70
Antero-posterior diameter of head	18
Transverse diameter of head	14
Transverse diameter of distal end	14

Metatarsal IV.—The fourth metatarsal is the longest in the series. Its head rises slightly above that on Mt. III, while the two bones extend equally far in the distal direction. The proximal face of the head has a large convex facet for the cuboid, while on the tibial side there is one facet situated on a prominent tubercle which fits into a corresponding pit on Mt. III, and the other facet for the same metatarsal is located on the plantar tibial angle, as stated above, thus causing these bones to firmly interlock, as in *Daphœnus*. On the plantar side there is a heavy tuberosity of cubical appearance and on the fibular side there is a deep pit similar to, though more pronounced than that for Mt. IV on the fibular face of Mt. III. Above this pit is a large facet which also articulates with Mt. V. The shaft is arched forward in the same degree as that on Mt. III, but is further differentiated from the latter by a prominent and rugose elevation for ligamentous attachments similar to that of *Daphœnus*. As in Mt.III the distal trochlea is quite symmetrical.

FIG. 53. Fibular and Dorsal Views of Right Metatarsal IV of *D. superbus*. Nat. size.

MEASUREMENTS OF METATARSAL IV.

	Mm.
Greatest length	73
Antero-posterior diameter of head	17
Transverse diameter of head	12
Transverse diameter of distal end	13

Metatarsal V.—The fifth metatarsal is of about the same length as Mt. II though slightly lighter. The head is greatly expanded, especially in the transverse diameter, due to the large development of the ascending fibular process, which is much more developed than in *Canis* and nearly equal in proportion to that of *Daphœnus*. On the posterior tibial side this process is succeeded by a heavy plantar tuberosity which extends throughout the remainder of the plantar face and rises above the articular facet on the proximal end. The tibial face has a projecting eminence carrying an articular facet for a corresponding pit on Mt. IV already described. The facet for the cuboid is quite large; it is slightly convex antero-posteriorly, and along the fibular border it is recurved upwards on the base of the ascending process referred to above, so that the facet is concave transversely and faces inward as well as upward like that of the older form. The shaft is well arched and has the usual transversely oval cross-section found in older types. The distal end is enlarged along the fibular border in about the same proportion as Mt. I is expanded on the tibial angle, giving the trochlea an oblique and asymmetrical appearance.

FIG. 54. Fibular and Dorsal Views of Right Metatarsal V of *D. superbus*. Nat. size.

Cynodesmus brachypus is an animal of considerably smaller size than *Daphœnodon*, but Mt. V, which is represented in the type, is of very nearly equal length, though much lighter than that of *Daphœnodon*. The ascending process on the fibular angle of the head is much larger than in *Canis*, but it is directed upward and outward pretty much as in the latter, and the articulation for the cuboid is small and faces directly upward as in the recent form, entirely unlike that of *Daphœnodon* and *Daphœnus*. Another modified character of importance in Mt. V of *C. brachypus* is seen in the shaft. The latter is more arched in the dorsal direction than in *Canis*, but it is plainly seen that the proximal half is trihedral, which is due to the more complete parallel arrangement of the metatarsals, approaching, condition found the in the modern *Canidæ*, while in *Daphœnodon* and its progenitors the upper portion of the shaft is transversely oval, due to a less appressed condition and a more

direct divergence from the proximal ends, which is a general feature of the early types of the *Miacidæ*.

MEASUREMENTS OF METATARSAL V.

	Mm.
Greatest length	62
Antero-posterior diameter of head	13
Transverse diameter of head	19
Transverse diameter of distal end	12

Sesamoids. — The sesamoids are proportionally somewhat smaller than in the recent canids, but have otherwise no noteworthy features differing from the latter.

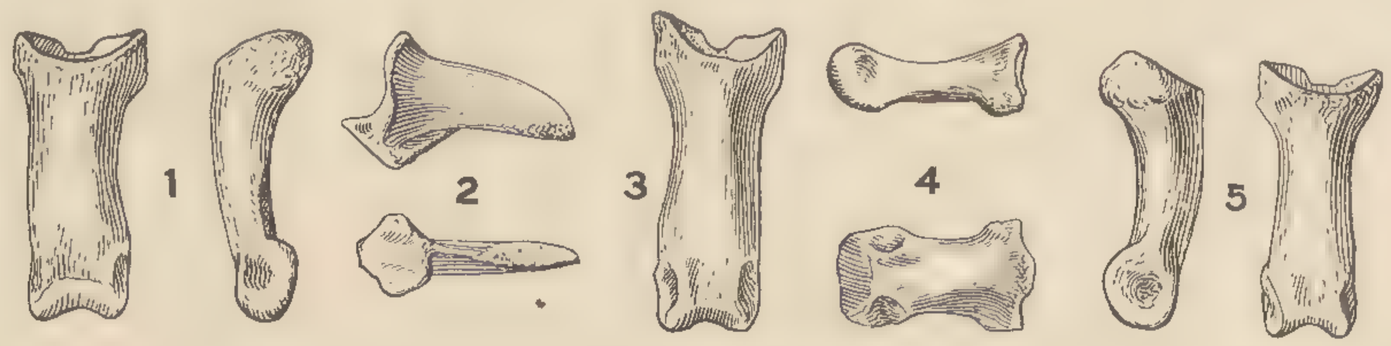


FIG. 55. Phalanges of Digits III, IV, and V, of Right Hind Foot of *D. superbus*. Nat. size. 1, dorsal and tibial views of first phalanx of third digit; 2, fibular and plantar views of terminal phalanx of third digit; 3, dorsal view of first phalanx of fourth digit; 4, tibial and dorsal views of second phalanx of fourth digit; 5, fibular and dorsal views of first phalanx of fifth digit.

Note: The hood of the ungual phalanx is partly broken off.

Phalanges. — The proximal row of phalanges are distinctly shorter in proportion to those in *Daphœnus*, which is also true of the phalanges of the manus. They are otherwise quite similar in structure, the proximal articulation being a concave pit with a broad plantar groove, and the distal trochlea confined principally to the plantar face. The median row of phalanges is asymmetrical in the same proportion as those in the manus, and indicate that the unguals were drawn toward the fibular borders when the little retractility which they undoubtedly possessed, was exercised. The unguals are similar to those in the manus.

MEASUREMENTS OF PHALANGES.

	Mm.
Greatest length of proximal phalanx, fourth digit	29
Greatest length of median phalanx, fourth digit	19
Greatest length of ungual phalanx, fourth digit	24

Restoration of *Daphœnodon superbus*.

(Plates LXXXIII and LXXXIV.)

The unusually well preserved and symmetrical bones of the type of *Daphœnodon superbus* have caused comparatively little trouble in correctly articulating the different parts of the skeleton. The restoration has been very well executed by Mr. Serafino Agostini. The mounted skeleton furnishes many additional features of the animal which only in this way can be fully appreciated.

The position of the head is as high in relation to the horizontal line of the vertebral column as the animal ordinarily held it in life. The long neural spines on the cervical vertebræ further indicate that the animal probably carried the head rather low. The curvature of the neck at the junction of the thorax is gentle, and the position of each dorsal vertebra increases in height until the lumbar region is reached, where a sudden downward curvature again takes place, not unlike that in the recent tiger. The twelfth and thirteenth dorsals have no facets for a tuberculum of the ribs as in *Felis tigris* and it is quite doubtful whether the eleventh dorsal of the present form carried a tubercular facet for the rib as the transverse process is poorly developed. The thorax was on the whole quite small, which is also characteristic of the Oligocence genus. The heads of the ribs of the left side (except the eleventh or twelfth) are all represented, while the shafts are restored after the more completely preserved ribs of No. 1589a. On the left side the ribs are poorly preserved, there being present only the heads and portions of the shafts of seven.

The fore limbs display a close similarity to those in *Daphœnus*. The deltoid and supinator ridges of the humerus are prominent, the former low down on the shaft, indicating the downward extent of the heavy muscles, while the development of the latter indicates the power of supination of the manus. Though the forearm is proportionally longer than in the latter genus the feet are remarkably little advanced, being short and broad, the pollex little reduced, and the position of the phalanges sharply angled as in the felines, but proportionally somewhat shorter than in *Daphœnus*. The power of retractility of the unguals was nearly as great as in the older form and no doubt still served the purpose of assisting in catching and holding the prey.

As has already been stated the posterior portion of the pelvis, portions of the femora, and the proximal ends of the tibiæ were unfortunately weathered out and disintegrated when the specimen was found, but from other material the comparative measurements were made, and the proportions, as they are in the skeleton represented on Pls. LXXXIII-LXXXIV, are thought to be approximately correct. The

hind feet are also quite broad, but somewhat longer than the fore feet, while the ungual phalanges of the former had apparently a power of retractility equal, or nearly equal, to that of the latter. Altogether the skeleton shows a long and comparatively slender body, long tail, and short and heavy limbs with broad and short feet.

MEASUREMENTS OF SKELETON.

	Cm.
Greatest length of vertebral column, the skull and all curvatures included	210
Length of vertebral column, atlas to posterior end of sacrum	92
Length of tail, approximately	88
Length of lumbar series	26.5
Length of dorsal series	33
Length of cervical series	21
Height of skeleton at first dorsal	57
Height of skeleton at first lumbar	61
Height of skeleton at supra-iliac border, approximately	58

NOTES ON INDIVIDUAL VARIATION OF *Daphœnodon*.

The superior dentition of the material at hand shows very little variation in general character, except in the young individual (No. 1589a) found with the type of *Daphœnodon superbus* and described on pages 210 and 215. The mandibular symphysis in some individuals however, is, longer, $p_{\overline{1}}$ has been dropped out and the alveole closed up, while $m_{\overline{3}}$ is sometimes inserted by two strong fangs.

In a series of cervicals (No. 1589b), the fourth, fifth, sixth, and seventh, which were found on the surface and in the talus at Quarry No. 3 (Agate Spring Fossil Quarries), are seen some differences from those described of the type of *Daphœnodon superbus*. These differences are most likely due to individual variation and sexual distinction, and will be thus treated in this connection pending the discovery of more material.

This cervical series is in the first place considerably heavier and pertains to a larger individual than the type specimen. Secondly, the ventral keels appear to terminate posteriorly in a more condensed rugose tubercle approaching more nearly that of *Canis* in its characters than to that of the type of *Daphœnodon*. Thirdly, the anterior projection of the transverse process of the sixth cervical vertebra in the series under consideration is much smaller than the corresponding portion in this vertebra of the type specimen. One of the more significant differences from the latter is seen in the sixth and seventh cervicals. The base of the neural spine of the seventh cervical is more nearly oval in cross-section, with no such excavations in front or back of the spine as is characteristic of the type specimen described above. The base of the spine of the sixth cervical is also without these excavations, so that

it is quite safe to say that this individual did not possess this character of the vertebræ. Another important feature is seen in the prominent antero-posterior ridge in the floor of the neural canal, which is pierced by a transverse venous foramen, while in the type specimen this ridge is rather poorly developed and the area in the middle region, where the foramen is located in the larger specimen, is much greater and was not always bounded above by a bony bridge so as to form a foramen. The transverse process is proportionally much shorter, which would indicate a narrower neck in the larger individual.

In the Amherst specimen, which is about equal in size to the one represented by the cervical vertebræ described above, there are some lumbar vertebræ preserved. One of these has the transverse processes preserved. These processes are proportionally longer than those in the corresponding region of the lumbars in the type, and more in accordance with the conditions found in *Daphœnus*, *Temnocyon*, and the recent forms. The os penis of the Amherst specimen of *Daphœnodon* is greatly different from that in No. 1589a (Carn. Mus. Cat. Vert. Foss.) and is described on pages 230 and 231.

Relationships of *Daphœnodon*.

That *Daphœnodon* had its true ancestor in *Daphœnus* of the Oligocene formation can hardly be doubted, from the study which has resulted in the above comparative description. *Daphœnus* in turn is generally regarded as a descendant of the *Miacidæ* of the earlier Tertiary of North America. In the Oligocene and early Miocene there were a number of diverging lines, which as a whole were nevertheless quite homogeneous in their general structure, though apparently sufficiently diversified to show with more or less clearness their destiny in later times. These points have already been ably treated by Scott, Boule, Schlosser, Matthew, Merriam, Hatcher, Wortman, and others, and will not be discussed in the present paper, except in so far as to assign the phyletic position of *Daphœnodon*.

It would appear that *Daphœnodon* is not yet represented by any very closely allied species[20] in the intervening formations from the lower Harrison beds down to the lower portion of the Oligocene where *Daphœnus*, its predecessor, is found. The genera from the John Day are already too far advanced in different ways to be seriously considered as intermediate forms. Thus *Temnocyon* and *Mesocyon* have $m^{\frac{3}{3}}$ absent and differ in many other important respects, some species[21] of the latter genus having a well developed entoconid on the lower sectorial, and being possibly

[20] *Mesocyon robustus* Matthew from the lower Miocene of South Dakota bears general similarities, but $m_{\frac{2}{2}}$ is apparently too much reduced and more trenchant, and $m_{\frac{3}{3}}$ is probably sometimes absent.

[21] *Mesocyon Josephi* (?). See Merriam, Univ. of Cal. Publications, Bull. Dept. Geol., Vol. V, pp. 19-20, 1906.

more nearly in the ancestral line of *Cynodesmus* (*C. brachypus*). *Philotrox, Hyænocyon,* and *Enhydrocyon* are removed from this line by the reduction of the premolars and other important features. *Paradaphœnus* is a small form with long narrow skull, deuterocone of $p^{\frac{4}{}}$ well internally, $M^{\frac{3}{}}$ aligned with the outer cusps of the anterior molars, heel of lower molars basin-shaped, and tympanic bulla of proportionally larger development.

Of the later American forms which are perhaps most closely related to *Daphœnodon, Amphicyon americanus* Wortman is quite well preserved and furnishes the most satisfactory comparison. This species, like the European, *A. major*, has the canines enormously developed and the premolars reduced when compared with *Daphœnodon.* $P_{\frac{4}{}}$ is less oblique in the alveolar border, $M^{\frac{1}{}}$ and $M^{\frac{2}{}}$ are apparently more nearly subequal in size, while $M^{\frac{3}{}}$ is aligned with the outside of the molars and is somewhat larger than in the latter genus. *Amphicyon major* of Europe is further differentiated from the present form by its short, broad, bear-like astragalus and sub-plantigrade hind feet.

Amphicyon lemanensis is another well known European form bearing certain resemblances to *Daphœnodon superbus,* but which on closer study displays numerous differences, among which mention may be made of a larger size three-rooted and tri-cuspid $M^{\frac{3}{}}$, a smaller $P^{\frac{4}{}}$, proportionally longer, narrower, and higher skull, as well as a differently constructed axis, and other characters of importance.

Amphicyon crucians, figured by Dr. Filhol (Ann. des Sciences Géologique, Vol. X, pl. 12, figs. 1–3, 1879) show only general similarity to *Daphœnodon,* so far as comparison can be made, the crowns of the premolars being higher and more pointed, and $P_{\frac{3}{}}$ having a basal tubercle, while that tooth in *Daphœnodon* has none.

Cephalogale geoffroyi is, with regards to the general features of the skull, more like *Daphœnodon,* but the proportions and construction of the tubercular molars are different, M^{3} being absent, and this European form is apparently no nearer related to *Daphœnodon* than for instance the American genus *Ælurodon.* In fact the apparent relations observed between the European and American forms here compared should perhaps be regarded as purely superficial and due entirely to independent development without necessarily close relationship.

With regard to the ancestry of the genus described above there can certainly be no doubt that we find in *Daphœnus* from the American Oligocene all the required characteristics pointing more clearly to *Daphœnodon* than they are so far found in any known European forms, the ancestral types of the latter genera having perhaps already occupied contemporaneously these European regions for a long time.

From the study of the osteology of *Daphœnodon superbus* it is quite evident that this genus belongs to a phylum existing through the Oligocene and Miocene periods, with rather conservative adaptations when compared with such forms as *Temnocyon*, *Mesocyon*, *Cynodesmus*, *Tephrocyon* and in fact with many coexisting forms of *Canidæ*. Although the genus should be, for the present at least, regarded as belonging to the subfamily *Amphicyoninæ*, it is not altogether unlikely that, upon gaining more complete knowledge of all the different supposed allied forms, it will be regarded as representing a separate subfamily (*Daphœninæ*) paralleling *Temnocyon*, *Mesocyon*, *Cynadesmus*, and *Tephrocyon* on the one hand and the true *Amphicyon* on the other, but less differentiated from *Daphœnus* than either of the genera regarded as descendants from the Oligocene forms. The phylum terminated, most probably, in some such forms as *Dinocyon* or *Borophagus*, or perhaps in some of the so-called *Amphicyones* in later formations of North America, while the *Amphicyoninæ* of Europe were paralleling the line.

This would seem to lend color to Mr. Hatcher's contention [22] that *Protemnocyon* and *Proamphicyon* are both valid genera, the former pointing to *Temnocyon* and *Mesocyon*, while the descendants of the latter, if not "*Amphicyon*" as Hatcher believed, may not yet have been discovered. The reduction or apparent absence of $M\frac{3}{-}$, together with other features in *Protemnocyon* from the Oligocene, is suggestive of the later John Day form, while $M\frac{3}{-}$ in true *Daphœnus* still persists in an almost unchanged form in *Daphœnodon* from the Miocene.

The bony structure of *Daphœnodon*, though extremely cat-like in many respects, is on the whole more closely related to the *Canidæ*, of which family it was an aberrant line not continued to the present time. A fairly good attempt has been made by Mr. Theodore A. Mills to construct the soft parts of *Daphœnus felinus*, from the skeleton which is now in the Carnegie Museum. And the curious combination of the characters of the cat and the dog are, if anything, even more striking when an allowance of flesh is represented upon the bony structure (see Pl. LXXXV). The downward extent of the heavy muscles of the limbs, the broad and short feet, with the semi-retractile claws, the long body and tail are especially cat-like, while the head is dog-like in every respect. The tail is represented more or less like that of *Felis concolor*, there being no perceptible means of knowing whether this appendage was bushy, as in the dogs, or more slender as in cats generally. Altogether the model represented by the figure on Pl. LXXXV is instructive, as it furnishes at least a conception of a primitive form ancestral to cats and dogs. Of this primitive stem *Daphœnus* and especially *Daphœnodon* on the whole, appear to be far less specialized

[22] "Oligocene Canidæ," *l. c.*, p. 105.

than most of their contemporaneous forms and consequently more nearly like the old types of the Miacidæ from the Eocene formations.

Canid (Undetermined Species).

A humerus (No. 2400) of a very large canid, the size of a lion, was found in the lower Harrison beds on Whistle Creek, Sioux County, Nebraska, about eight or ten

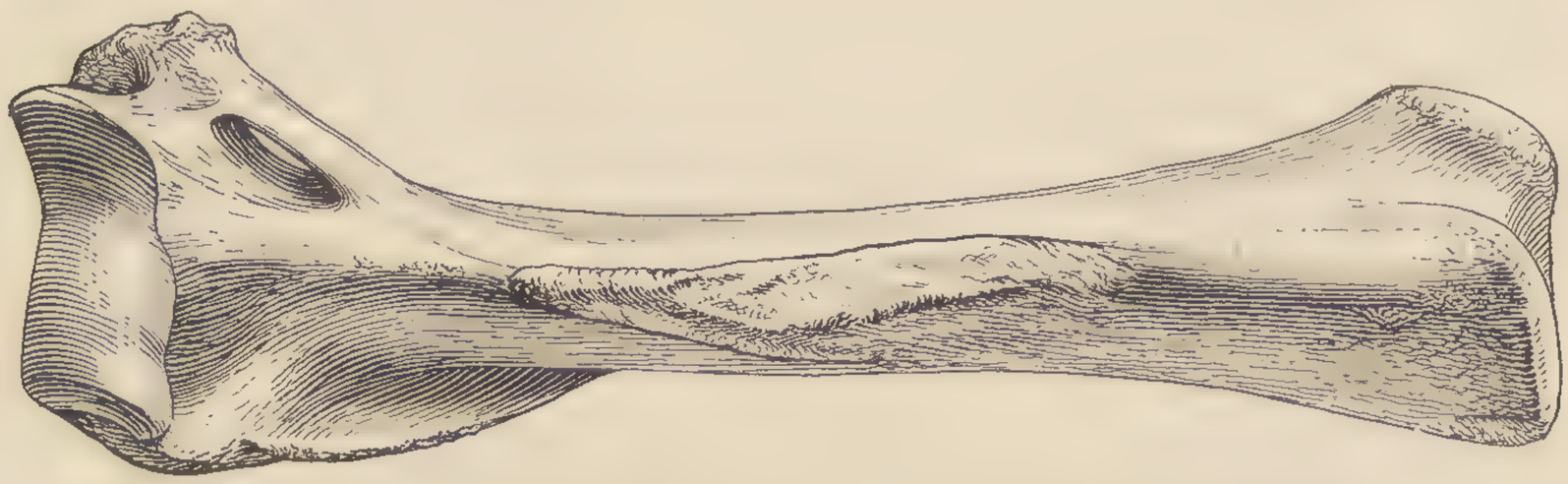


FIG. 56. Anterior View of Humerus of Canid. Sp. indt. ½ nat. size. No. 2400.

miles east of the Agate Spring Fossil Quarries. With the exception of its greater size and the greater distal extent of the deltoid ridge this humerus most nearly resembles that of *Daphœnodon*. The bone is very nearly the size of the humerus of *Amphicyon major* of Europe and not unlike the latter, so far as comparisons can be made. In the American species, however, the deltoid ridge extends lower down and the anconeal fossa is not so high as in the European species. The humerus possibly represents some genus closely related to such large forms as *Dinocyon* from the later Tertiary of Montana described by Mr. E. Douglass[23] or *D.* (*Borophagus*) *gidleyi* from the Miocene of Texas described by Dr. W. D. Matthew.[24] The quarry in which the humerus (fig. 56) was found contains a similar fauna to that of the Agate Spring Fossil Quarries.

FIG. 57. Fibular and Anterior Views of Calcaneum of Canid sp. indet. ½ nat. size. No. 2211.

A fifth metacarpal (No. 1897) of a large carnivore, which may belong to this species, was found by the writer in 1904 among the surface fragments in the quarry, which was worked the following years by Professor Barbour (Agate Spring Fossil

[23] "New Vertebrates from the Montana Tertiary," Ann. Car. Mus., Vol. II, p. 192, 1903.

[24] "A Skull of Dinocyon from the Miocene of Texas," Bull. Amer. Mus., Vol. XVI, p. 129, 1902.

Quarries, "University Hill" Quarry). This bone is very heavy, short, and much arched in the dorsal direction. A calcaneum of nearly an equally large carnivore was found in the same horizon north of the Niobrara River in this general locality and is illustrated on page 262, Fig. 57. The remains indicate the presence of these large carnivores in the fauna found in these quarries.

MEASUREMENTS.

	Mm.
Greatest length of humerus	305
Greatest antero-posterior diameter of head	87
Greatest transverse diameter of head	68
Greatest length of Mc. V	63
Greatest length of calcaneum	90
Greatest transverse diameter at sustentacular facet	45

Borocyon* **robustum** gen. et sp. nov.

Type: (No. 1918, Carn. Mus. Cat. Vert. Foss.) Front of right ramus, caudal vertebræ, fragments of manus, part of hind limb and foot, and various other fragments.

Horizon: Miocene, Upper Harrison beds.

Locality: Whistle Creek, Sioux County, Nebraska.

Mr. T. F. Olcott, while engaged with the Carnegie Museum party in 1905, discovered and collected this specimen about four or five miles southeast of the Agate Spring Fossil Quarries. As indicated above it was found in the upper Harrison beds. Although the type is fragmentary it enables me to give some characters which may be regarded as of generic value. The type is perhaps more closely allied to such forms as *Amphicyon sinapius* Matthew from later horizons than to *A. americanus*, *A. ursinus*, or any of the European forms with which it has been compared. The jaw is undoubtedly quite short and heavy, and the premolars are of considerable size when compared with *A. ursinus*. The portion of the jaw preserved compares fairly well with *Ælurodon taxoides* Hatcher, but the canine is heavier and $P_{\overline{2}}$ has no posterior cusp as in that species. *A. meandrinus* had the jaw proportionally longer in front of $P_{\overline{1}}$ than the present genus. It is, of course, quite provisionally that this genus is placed in the *Daphœnus-Daphœnodon* phylum, but pending the discovery of more complete material it would seem most satisfactory from the study of the limb and foot structure to regard the genus as a later member of this aberrant line. The material represents an animal nearly the size of a fully adult lion.

Generic characters. Canine proportionally large and oval in cross-section, $P_{\overline{1}}$ single-rooted, $P_{\overline{2}}$ low-crowned with protoconid well anteriorly, no posteriar cusp, and a large

* *βορός* = greedy; *κύων* = dog.

posterior base, $M_{\overline{3}}$? present, heavy and elongated tail, limbs and feet well proportioned and sub-digitigrade as in Daphœnus and Daphœnodon, little or no retractility of the unguals.

General Description and Specific Characters.

The material represents a fully adult animal judging from the much worn canine. The latter is oval in cross-section and is proportionally larger than that tooth in *Daphœnodon*. Judging from the abraded anterior face of the canine it is quite evident that $I^{\overline{3}}$ was of large size as in *Daphœnodon*. The postero-external angle of the canine is also worn by the contact with the upper canine. As in

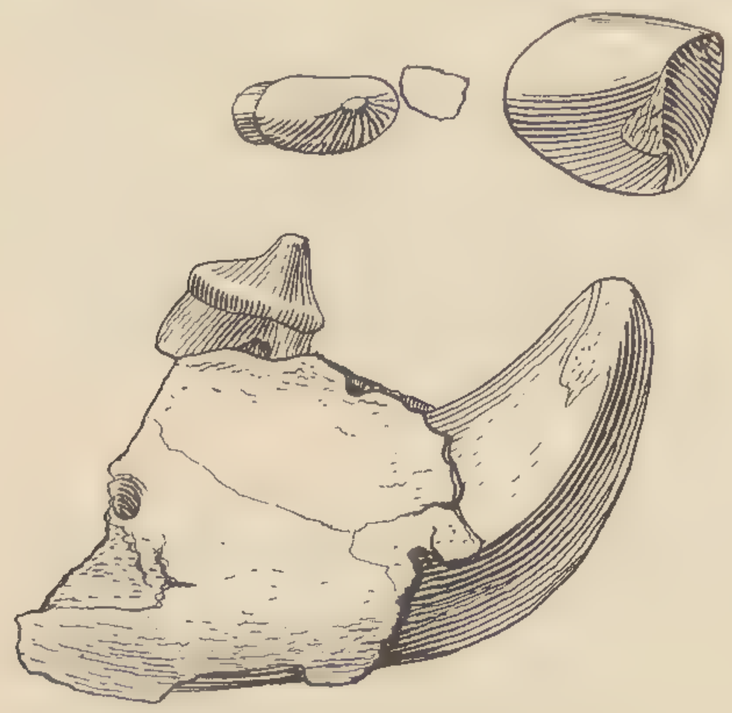


Fig. 58. Right Side of Lower Jaw-fragment and Crown View of Teeth of *Borocyon robustum*. Nat. size. No. 1918.

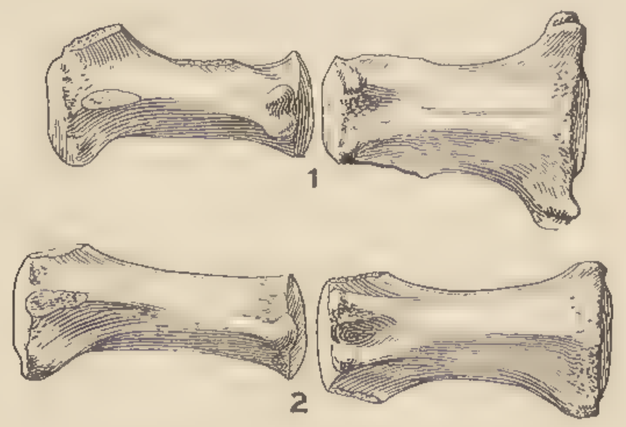


Fig. 59. Caudal Vertebræ of *Borocyon robustum*. ½ nat.? size. No. 1918. 1, lateral and ventral views of caudal 7; 2, lateral and ventral views of caudal? 9.

Daphœnodon there is a short diastema back of the canine. $P_{\overline{1}}$ is single-rooted. $P_{\overline{2}}$ is low-crowned and has the protoconid placed more anteriorly than in *Daphœnodon*, which results in a less developed anterior and greater posterior base than on $P_{\overline{2}}$ in the latter genus. There is no posterior tubercle on $P_{\overline{2}}$ as in *Ælurodon*, but the cingulum is well developed; it surrounds the tooth and is smooth on the external side, while internally it is slightly mammilated. There is a large mental foramen directly under the posterior portion of $P_{\overline{2}}$. The symphysis is quite heavy and extends well back as in *Daphœnodon*.

The only parts present representing the vertebral column in the type are a number of caudal vertebræ from different regions of the tail. The centra of these vertebræ are long and heavy, indicating a tail of approximately the same proportions as that of *Daphœnodon*.

The manus is represented by a complete trapezoid, Mc. I, and other fragments. The trapezoid is depressed and wide transversely, indicating a broad manus. The

facet for the scapho-lunar is slightly convex from before backward near the dorso-radial angle, while further back and along the ulnar portion it is concave in the same direction. Radially there is a large facet for the trapezium, which takes up nearly the entire face. On the ulnar side the facet, for the lunar, meets that for the magnum at an acute angle so as to form a prominent ridge, which extends a short distance back from the dorsal border. Back of the ridge the ulnar face is taken up by a large rugose area for the attachment of muscles and ligaments. On the distal face there is a large subtriangular articulation for the second metacarpal.

The free end of the pisiform indicates this bone to be quite like that in *Daphœnodon.*

Mc. I has the head less expanded transversely, the shaft less arched forward, and less curved outward at the distal end than that of *Daphœnodon superbus;* there is otherwise little or no difference between this bone in the two forms. Other fragments of the metacarpals suggest heavy bones in this region.

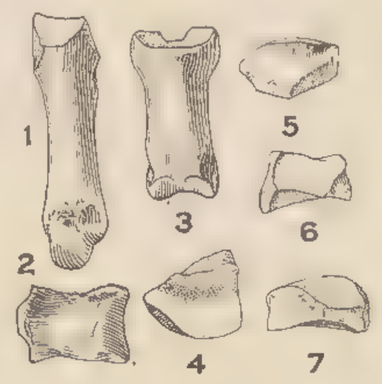


FIG. 60. Foot Bones of *Borocyon robustum.* ½ nat. size. No. 1918. 1, dorsal view of metacarpal I; 2, dorsal view of a second phalanx; 3, dorsal view of a first phalanx; 4, proximal view of trapezoid; 5, dorsal view of trapezoid; 6, radial view of trapezoid; 7, ulnar view of trapezoid.

The phalanges are proportionally short when compared with *Daphœnodon.* Those of the proximal row are otherwise arched in the dorsal direction similar to the conditions found in the latter genus, while the median phalanx is depressed and broad. There is no ungual phalanx present with the type.

The hind limb is represented by the lower half of the tibia and fibula, the astragalus, navicular, ento-, meso-, and ectocuneiforms, and other fragments.

With the exception of the proportionately somewhat greater antero-posterior diameter of the distal end, the tibia offers little or no characteristic differences by which it may be distinguished from that of the smaller genus. The distal end of the fibula is more compressed laterally than in *Daphœnodon;* otherwise there is also little difference in this bone in the two forms.

The astragalus has a slightly longer neck and the articular surface of the trochlea descends lower than in *Daphœnodon,* otherwise this bone does not differ in the two genera. The principal difference of the navicular from that of *Daphœnodon* is seen in the smaller development of the plantar tuberosity; the rugose area for muscular attachment slanting more upward and backward, resulting in the comparatively small vertical diameter of the tuberosity. The entocuneiform is quite large, and of good proportionate vertical diameter. The tibial plantar angle is more

concave in the vertical direction than in *Daphœnodon*, which results from the greater development of the ascending plantar tuberosity of the present form. The meso- and ectocuneiforms are similar to those in *Daphœnodon*.

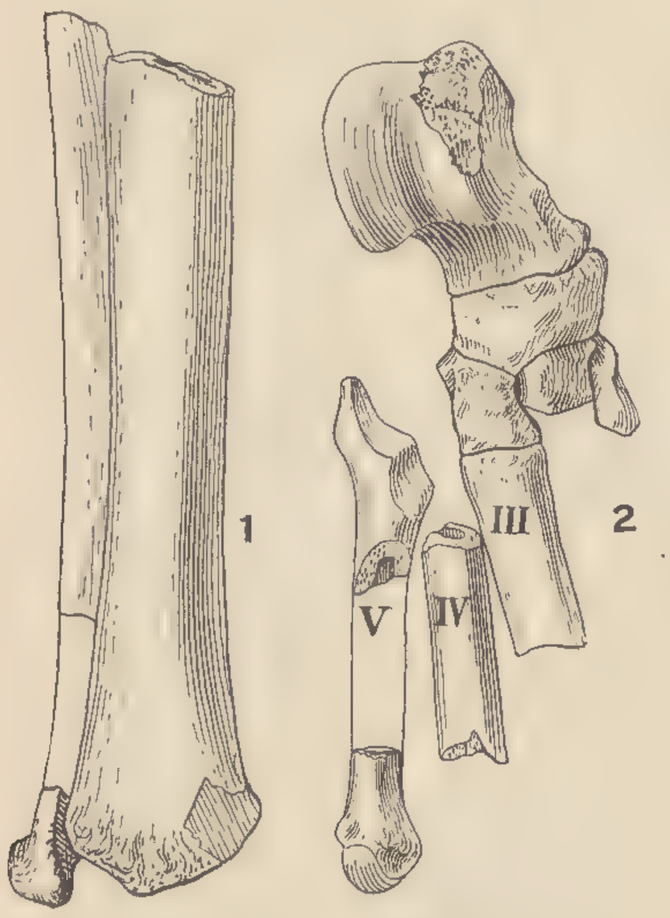


FIG. 61. Fragments of Hind Limb and Foot of *Borocyon robustum*. ½ nat. size. No. 1918. 1 dorsal view of tibia and fibula ; 2, dorsal view of hind foot.

Metatarsal III has the articular surface for the ectocuneiform less oblique and the tibial and fibular faces of the head less excavated than in *Daphœnodon*. Mt. V is quite unlike that of the latter genus in respect to the articular facets of its head. The tibial face has a somewhat smaller facet for Mt. IV and the facet for the cuboid is entirely proximal, while in *Daphœnus* and *Daphœnodon* the facet for the cuboid extends well in the fibular direction, encroaching on the base of the ascending process so as to form a lateral as well as a proximal contact with the cuboid. Another important difference from the older forms is seen in the vertical position of the ascending process on the fibular face of the head. In the Oligocene and Miocene forms, here used for comparison, this process is very heavy and projects upward and outward forming, with the excavation for the peroneus longus tendon on the cuboid, a transversely broad groove. In the present genus the ascending process, though large, is directed more vertically and the space between it and the fibular face of the cuboid is comparatively narrow. Near the proximal ends the shafts of the meatarsals are slightly triangular in cross-section. The distal end of Mt. V? is somewhat less expanded transversely than in *Daphœnodon*, but the trochlea is quite similar, being very convex dorsally and separated by a prominent carina on the plantar aspect.

MEASUREMENTS.

	Mm.
Antero-posterior diameter of canine at base	21
Transverse diameter of canine at base	15
Antero-posterior diameter of $p_{\overline{2}}$	14
Transverse diameter of $p_{\overline{2}}$	18
Vertical diameter of ramus at $p_{\overline{2}}$	35
Length of ? ninth caudal	58
Antero-posterior diameter of trapezoid	19
Greatest transverse diameter of trapezoid	20

Greatest vertical diameter of trapezoid	12
Length of Mc. I	49
Greatest transverse diameter of head Mc. I	12
Greatest length of proximal phalanx of 3rd or 4th digit	31
Greatest length of median phalanx of 3rd or 4th digit	21
Height of tarsus	86
Transverse diameter of tarsus, approximately	58
Height of astragalus	50
Greatest transverse diameter of astragalus	40
Greatest transverse diameter of trochlea of astragalus	28
Antero-posterior diameter of navicular	30
Greatest transverse diameter of navicular	36
Greatest vertical diameter of navicular	18
Antero-posterior diameter of entocuneiform	17
Transverse diameter of entocuneiform, distal end	7
Vertical diameter of entocuneiform	25

Cynodesmus thomsoni Matthew.

Bull. Amer. Mus. Nat. Hist., Vol. XXIII, p. 186, 1907.

This species is represented by a considerable portion of a skeleton (No. 1529, Carn. Mus. Cat. Vert. Foss.) found in the upper Harrison beds on the Niobrara River, Sioux Co., Nebraska, and adds to our knowledge of that species. According to Dr. Matthew's statements there are apparently no hind feet with the type, while in the present specimen both fore and hind feet are quite well preserved and indicate about the same proportionate size as those of *Cynodesmus brachypus*. In fact most of the skeletal features are quite similar to those of the latter species so far as they can be compared. $P\frac{4}{-}$ is absent on both sides and considerable crushing has taken place at the base of the skull of *C. brachypus* which prevents a very accurate comparison, but it is quite evident that $M\frac{2}{-}$ is fully as much reduced comparatively as in *C. thoöides* Scott, and is considerably smaller than in the type of *C. thomsoni* and the specimen in our collection referred to the latter species. These and other differences of the dentition no doubt indicate more progressive development in *C. brachypus* and *C. thoöides* so far as certain features of the dental structure are concerned. The structure of the feet and limbs certainly approaches very much nearer the conditions found in *Canis* than is the case in *Daphœnodon*. Among these may be mentioned the higher position of the deltoid crest, the less prominent supinator ridge of the humerus, the reduced distal end of the ulna, the laterally expanded supra-iliac border the concave gluteal surface and shorter ischium of the pelvis, the more completely grooved astragalus, the proportionally greater length of the metatarsals over the metacarpals, the tendency of the metatarsals to become appressed at their proximal ends, and the more reduced pollex and hallux.

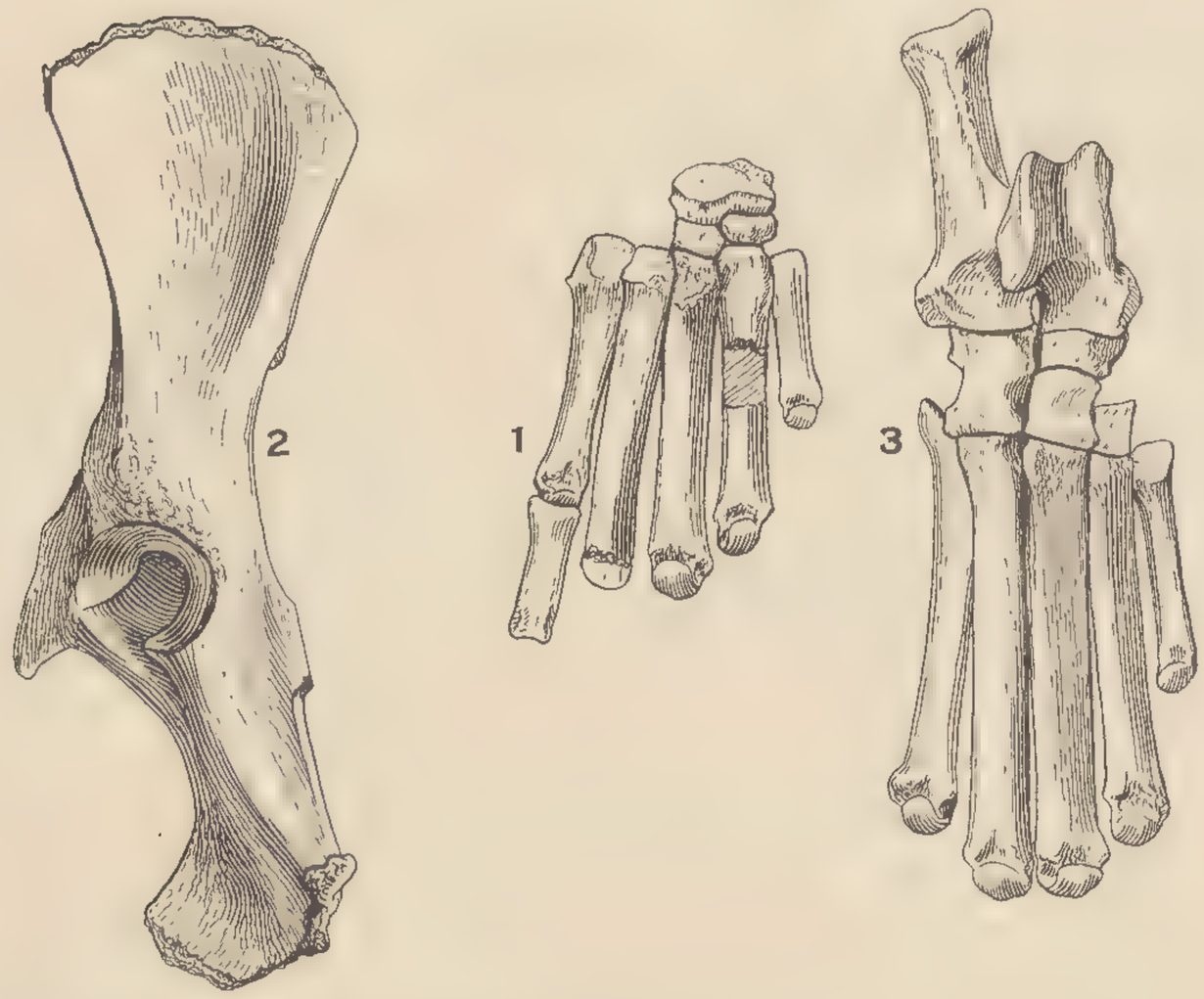


FIG. 62. Pelvis and Feet of *Cynodesmus thomsoni* Matthew. Nat. size. No. 1591. 1, anterior view of manus; 2, external view of pelvis; 3, anterior view of pes.

When the skull of the present specimen (No. 1591) is compared with Matthew's description and figures (*l. c.*, pp. 186–188) it is seen that in practically all the details of structure, except the apparently smaller brains in our specimen, which may be due to crushing, the two specimens agree quite closely. $P_{\overline{2}}$ in the Carnegie Museum specimen has no posterior cusp, while Dr. Matthew's figure indicates one on the type. The present specimen represents an old individual, as the tubercular teeth are much worn.

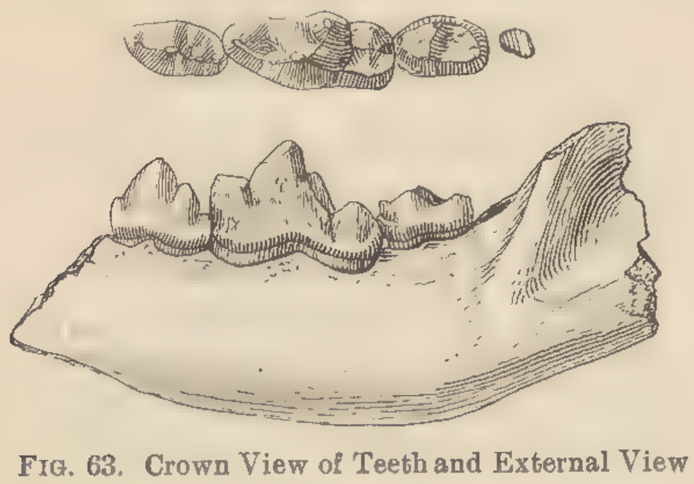


FIG. 63. Crown View of Teeth and External View of Jaw-fragment of *Tephrocyon* (Canis) *temerarius* Leidy. Nat. size.

Tephrocyon (Canis) temerarius Leidy.

Proc. Acad. Nat. Sci. Phila., p. 21, 1858; Jour. Acad. Nat. Sci., Vol. VII, p. 29, Pl. I, fig. 12, 1869.

A fragment of a lower jaw (No. 2404, Carn. Mus. Cat. Vert. Foss.) is provisionally referred to this species as the measurements and general appearances are quite close to those of the type. The present specimen was found on Whistle Creek, Sioux

County, Nebraska; it was lying on the surface and possibly pertains to a later Miocene or Pliocene deposit which apparently thinly covers the lower Miocene section in certain places in this valley. The accompanying figures are given in order to show the close similarity of this species to *T. rurestris* Merriam and *T. hippophagus* Matthew and Cook.[24] The only differences between the present form and *T. hippophagus* so far as comparison can be made, is the smaller size and the slightly slenderer jaw of *T. temerarius.*

MUSTELIDÆ.

Paroligobunis (Brachypsalis) simplicidens *gen. nov.*

Annals Carnegie Museum Vol. IV, pp. 44–46, 1906.

Type: Right mandibular ramus (No. 1553, Carn. Mus. Cat. Vert. Foss.).

Horizon: Lower Harrison beds (Miocene).

Locality: Near Agate Spring Fossil Quarries, Sioux County, Nebraska.

Plesiotype: Left mandibular ramus, greater portion of femur, fibula, and bones of fore and hind foot (No. 2389, Carn. Mus. Cat. Vert. Foss.).

Horizon: Lower Harrison beds (Miocene).

Locality: Agate Spring Fossil Quarries (quarry No. 3), Sioux County, Nebraska.

Generic Characters. — Dentition, $\frac{?3.1.4.2.}{}$. *Canine heavy and oblong in cross-section. Premolars crowded, heavy, rather bluntly crowned, no accessory posterior cusps except on* $p_{\overline{4}}$. *Carnassial comparatively large, approaching condition in recent forms (Gulo), but possesses a small entoconid which is located high up on the crown.* $M_{\overline{2}}$ *much reduced in size. Femur longer than the tibia in the same proportion to that in Meles or Gulo. Feet broad and short; pes sub-plantigrade; unguals not retractile.*

GENERAL DESCRIPTION OF THE PLESIOTYPE AND SPECIFIC CHARACTERS.

The lower jaw is only very slightly larger than that in the type of this species previously described and is much larger than *Meles taxus.* The mandible below $p_{\overline{3}}$ is very deep and the posterior mental foramen is located directly below the posterior fang of $p_{\overline{3}}$. Judging from the bottom of the alveolus for the canine, that tooth was strongly developed and the premolars appear to have been crowded, as in the type.

The inferior border of the horizontal ramus is gently convex in the fore-and-aft direction, as in the type. Opposite the vertical ramus the inferior border is only slightly raised as in *Gulo luscus* and unlike that in *Meles,* in which the angle is higher. The posterior portion of the lower jaw as a whole is otherwise very like that of the latter genera; possessing a large and deep temporal fossa, a large

[24] Matthew, W. D., and Cook, Harold J., Bull. Amer. Mus. Nat. Hist., Vol. XXVI, p. 373, 1909.

coronoid process, transversely broad and well rounded condyle, heavy masseter ridge, and prominent hook-like angle. The condyle is on a horizontal line with the dentition and is slightly lower than in *Meles taxus* and more like that of *Gulo luscus*. The ramus is broken in the region of $p_{\overline{1}}$ but this tooth is present in the type. $P_{\overline{2}}$ is

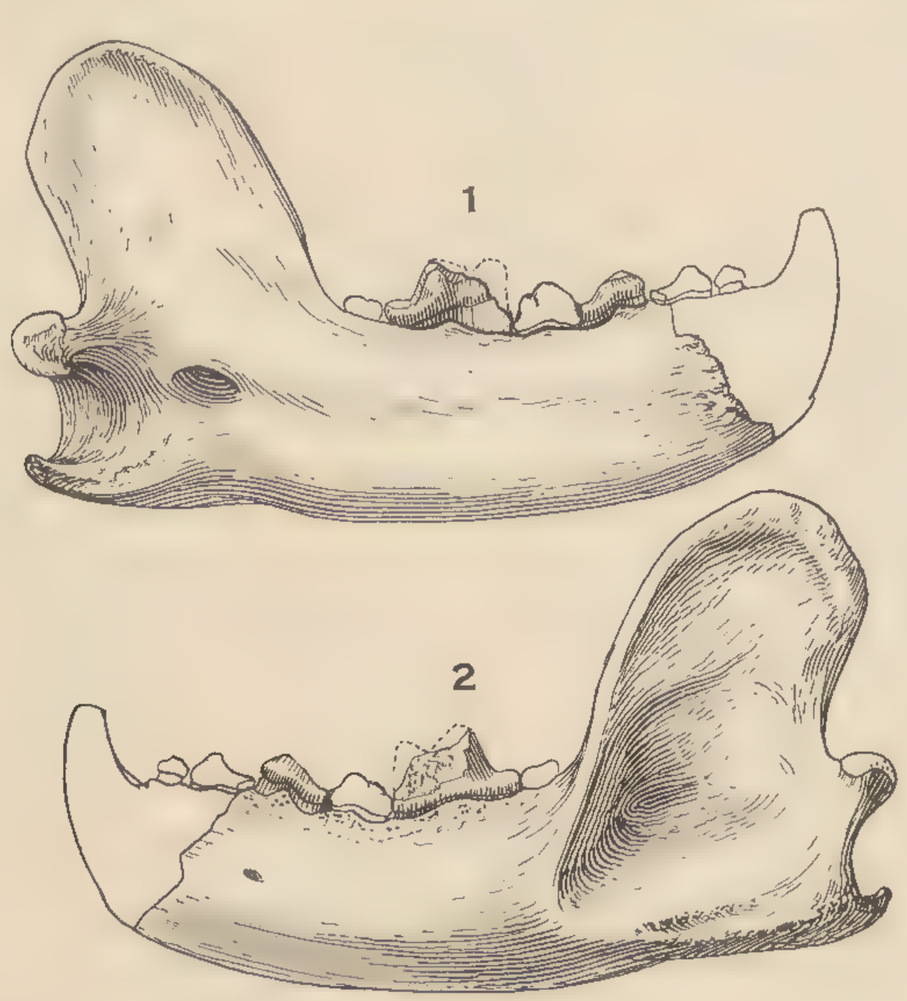


FIG. 64. Lower Jaw of *Paroligobunis simplicidens*. $\frac{2}{3}$ nat. size. 1, internal view of jaw; 2, external view of jaw.

of considerably large size judging from the posterior root, which is still in position in the jaw. $P_{\overline{3}}$ is robust, and, as in the type, has a great transverse diameter with the protoconid placed well anteriorly. Internally there is a smoothly rounded cingulum, which continues from the antero-internal angle of the tooth, as in *Gulo luscus*, and is somewhat more developed than in the type. The crown of the tooth is much abraded showing that the animal was fully adult. Back of $p_{\overline{3}}$ is a space of 11 mm. for $p_{\overline{4}}$. $M_{\overline{1}}$ is unfortunately broken anteriorly so that the blade cannot be described. The metaconid is preserved and is rather small and placed high up on the crown. The heel is of moderately large size with the hypoconid well developed, forming the external edge of the heel, while the entoconid is probably absent.[26] Back of $m_{\overline{1}}$ there is a small alveolus, indicating a single-rooted tooth, which was even smaller than that tooth in the type. The contour of the lower jaw and especially the dentition are on the whole rather more suggestive of *Gulo luscus* than *Meles taxus*.

[26] The abraded condition of the tooth does not admit of a positive statement as to the presence or absence of an entoconid.

MEASUREMENTS OF MANDIBLE.

	Mm.
Total length of the ramus fragment	110
Antero-posterior diameter of P_3	11
Greatest transverse diameter of P_3	8
Antero-posterior diameter of M_1 approximately	18
Greatest transverse diameter of heel	8

Manus. — The manus is represented by a number of metacarpals of both sides, the unciform and trapezoid of the right foot and a phalanx; the latter may equally well belong to the hind foot.

The unciform is of very nearly the same proportionate height, but of less transverse diameter than in *Meles taxus;* the facet for the cuneiform descends on the ulnar side to about the same extent as in the recent form, while the facet for the scapho-

FIG. 65. Right Mandibular Ramus of *Paroligobunis simplicidens.* ⅔ nat. size. Type No. 1553. 1, external view; 2, crown view of teeth.

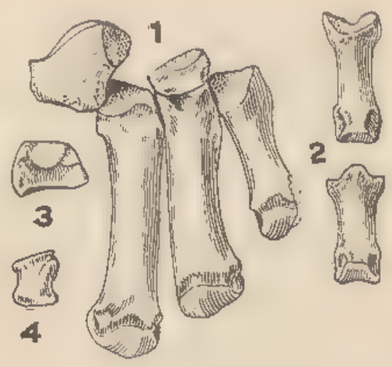


FIG. 66. Foot Bones of *Paroligobunis simplicidens.* ⅔ nat. size. No. 2398. 1, dorsal view of portion of right manus; 2, dorsal view of a first and second phalanx; 3, tibial view of mesocuneiform; 4, dorsal view of mesocuneiform.

lunar occupies a liberal portion of the radial angle. The facet for the magnum is continuous from the distal to the proximal face, as in *Daphœnus* and *Daphœnodon,* but the lunar facet is more distinctly separated from the facet for the magnum than in the latter genera. This is due to a prominent sinuous ridge, which extends from the dorsal border, obliquely upward and backward so that the upper portion of the facet for the magnum is concave supero-inferiorly, while the lower portion is plane antero-posteriorly; the facet for Mc. III near the distal face is convex antero-posteriorly. The palmar tuberosity is compressed transversely; it is more prominent than in *Meles taxus* or the recent otter, but does not extend so high up upon the palmar face as in *Daphœnus* or *Daphœnodon.* Distally the bone is much expanded and the articulations for Mc. IV and V are transversely broad and concave in the antero-posterior direction.

The trapezoid is quite depressed and triangular in outline. Its proximal face

slants excessively downward in the ulnar direction, meeting the facet for Mc. II at an acute angle, so as to form a prominent and sharp ridge, which extends a short distance from the dorsal face backward almost identical with that in *Meles* and *Lutra*. Back of this ridge on the ulnar face is a rugose area for muscular attachments, the bone terminating palmarly in a round obtuse point. Distally the surface for Mc. II is convex transversely, the radial side less strongly than the ulnar, while antero-posteriorly the articulation is very slightly concave. The radial face is taken up almost entirely by the large facet for the trapezium. The latter is undoubtedly of large size judging from the large facets on the trapezoid and on Mc. I.

The first metacarpal is rather short when compared with that of *Gulo*, or even with that of the recent badger, and is more like that in the otter; it is also proportionally shorter than that in *Megalictis ferox* Matthew from the lower Miocene of South Dakota. The proportionate length of the metacarpals as a whole agree quite closely, however, with those in the latter genus. The facet for the trapezium is, as stated, of large size, and it is obliquely convex antero-posteriorly, extending well down on the shaft as in *Meles*, and is not unlike that of *Megalictis ferox* Matthew and *Ælurocyon brevifacies* Peterson.[27] The shaft has received some injury in the process of collecting, but enough is preserved to show that it was heavy, well arched forward, and quite cylindrical. The distal trochlea is fully developed and carried the usual two phalanges.

The second metacarpal is quite heavy and in its general proportion it compares well with that in *Megalictis*. The head rises above that on Mc. III, so that the ulnar face has a facet for the magnum similar to that in *Meles*, while in *Megalictis* the head is apparently raised higher (see illustration, fig. 15, of Dr. Matthew's paper, *l. c.*). The facet for the trapezoid is concave transversely, the ulnar angle being higher than the radial. The palmar tuberosity is a hemispherical knob, while radially the head has an uneven surface for muscular attachment. On Mc. II of the right side there is no articular facet for Mc. I, while the one on the left side has a small facet near the dorsal angle. The origin of this facet may, in part, be due to injury received in this region, which is plainly shown by the rough surface of the proximal portion of the bone. The shaft is very heavy, slightly arched forward, and transversely oval in cross-section. The dorsal portion of the trochlea is not nearly as hemispherical as in *Daphœnus*, while plantarly it is divided by a prominent carina, the radial portion occupying a higher position than the ulnar, causing asymmetry of the trochlea.

[27] See fig. 19, 5, Ann. Carn. Mus., Vol. IV, p. 71, 1906.

The third metacarpal is no heavier than the second, though longer. The articular facet for the magnum slants inwardly, but the radial border is not raised as in *Daphœnodon* so as to form a transverse concavity, but instead it is very nearly plane transversely and evenly convex antero-posteriorly. On the radial side is a facet for Mc. II which is succeeded, posteriorly, by a deep sulcus, the palmar tuberosity forming its posterior border. On the ulnar side the proximal end is excavated in order to accommodate the head of Mc. IV and the articular facet for the unciform is concave due chiefly to the development of the dorso-ulnar angle of the head. The shaft is very slighty arched and transversely oval, due to the divergence of the metacarpals directly from the proximal end as in the mustelids generally. The trochlea is more symmetrical than that of Mc. II.

MEASUREMENTS.

	Mm.
Unciform, greatest antero-posterior diameter	13
Unciform, greatest transverse diameter	12
Unciform, greatest vertical diameter	15
Trapezoid, greatest antero-posterior diameter	10
Trapezoid, greatest transverse diameter	9
Trapezoid, greatest vertical diameter	6
Metacarpal I, greatest length	26
Metacarpal II, greatest length	37
Metacarpal III, greatest length	41
Median phalanx, greatest length	17

A proximal phalanx of the pollex or hallux has the proximal end much expanded, the shaft strongly arched and of considerable length, while the distal trochlea is confined principally to the plantar face. A median phalanx found with the specimen is much depressed, quite long, and does not indicate retractility of the ungual.

THE HIND LIMB.

The greater portion of the femur is preserved. The head is well rounded and sits on a long neck, as in *Meles*, *Lutra*, and *Gulo*. The pit for the ligamentum teres is located on the posterior half near the lower border. Unfortunately the great trochanter, together with the upper portion of the shaft, is lost on its external side, while internally the shaft is preserved, showing a large lesser trochanter. On the lower half of the shaft the fibular border is produced into a very prominent ridge, which is even more pronounced than in *Meles taxus* or *Gulo luscus* and terminates below in a rugose tubercle similar to that of *Canis*. The lateral development of the shaft gives it the characteristic transversely broad appearance seen in *Gulo luscus* or *Meles taxus*. The rotular trochlea is shallow and broad, the condyles have great trans-

verse diameter and are separated by a rather shallow groove, the external condyle being quite oblique to the long axis of the bone.

The fibula is heavy and has the proximal and distal ends much expanded. The shaft sweeps gently towards the shaft of the tibia and is also gently arched in the backward direction. The facet for the astragalus is nearly plane and the posterior face has the tendinal groove and external malleolus fully as well developed as in the recent badger or otter.

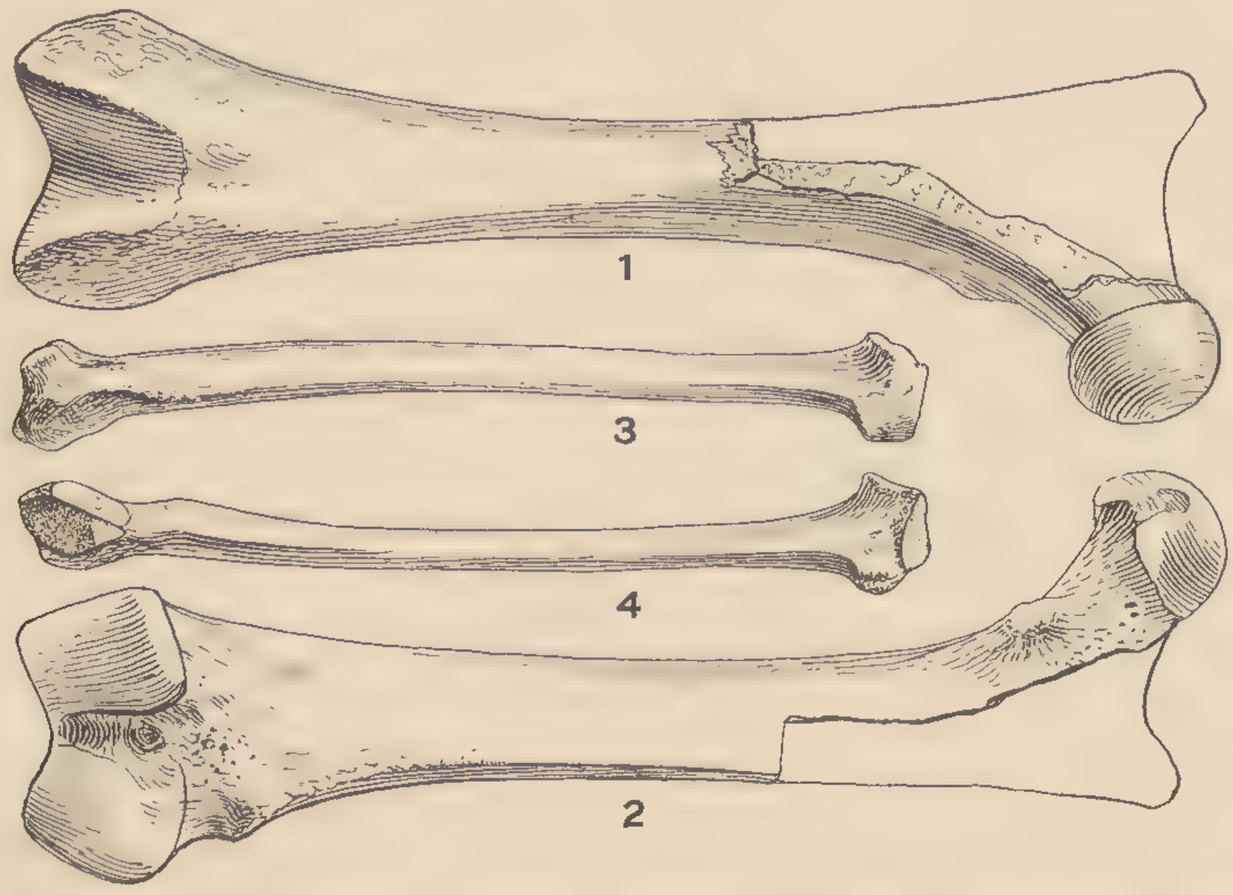


FIG. 67. Limb Bones of *Paroligobunis simplicidens*. ⅔ nat. size. 1, anterior view of femur ; 2, posterior view of femur ; 3, fibular view of fibula ; 4, anterior view of fibula.

Both astragali are represented. In comparison with the length of the bone the trochlea is somewhat narrower than that of *Megalictis ferox*. The trochlea is very shallow and is more oblique and imperfect than in either *Meles* or *Lutra* and rather more like that of *Gulo luscus*, the internal condyle being less developed, while the external is higher than in the two recent forms first mentioned. The tibial face of the internal condyle is not interrupted by the sulcus, which is so characteristic of *Daphœnodon*, but is continuous as in *Gulo* and *Meles*. The posterior limit of the trochlea, as well as its downward extent on the neck of the anterior face, is approximately in the same propor-

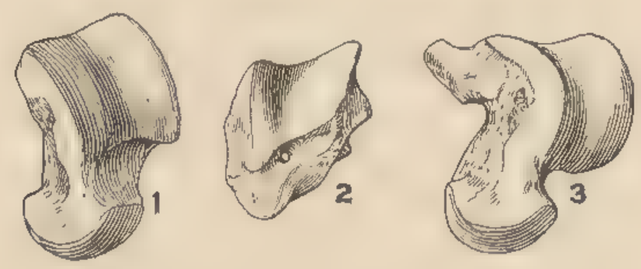


FIG. 68. Astragalus of *Paroligobunis simplicidens*. ⅔ nat. size. 1, anterior view; 2, superior view ; 3, tibial view.

tion to that in the recent forms. One of the more curious features of the bone is the deep and obliquely placed sulcus, which separates the groove for the flexor muscles from the astragalar trochlea. In this groove is located the astragalar foramen (see fig. 68, 2), which pierces the bone and again appears in the groove between the internal and external facets for the calcaneum on the plantar face, as in *Meles taxus*. The neck is perhaps somewhat longer than in *Megalictis*, which again reveals a tendency towards *Gulo luscus*. The head is also expanded and convex in the same way.

A mesocuneiform which was found with the specimen and very likely belongs with it, is high and narrow when compared with *Meles*, and is apparently also slightly higher in proportion to that of *Megalictis*, but is otherwise quite like that of the latter, the tibial face possessing a large facet for the entocuneiform.

MEASUREMENTS.

	Mm.
Femur, length from head to distal end	174
Femur, transverse diameter of distal end	42
Femur, antero-posterior diameter of distal end	36
Fibula, greatest length	130
Astragalus, greatest length	33
Astragalus, greatest transverse diameter	26
Astragalus, greatest transverse diameter of trochlea	16
Mesocuneiform, greatest antero-posterior diameter	11
Mesocuneiform, greatest transverse diameter	6
Mesocuneiform, greatest vertical diameter	8

AFFINITY AND SYSTEMATIC POSITION OF *Paroligobunis*.

While some features of the limbs in *Paroligobunis simplicidens* suggest that of *Lutra; i. e.*, the oblique and limited posterior extent of the internal condyle of the femur, the backward sweep of the shaft of the fibula, the proportionate length and arrangement of the metacarpals; there are more important characters which very strongly suggest that the animal was probably fossorial rather than aquatic in his habits. The femur is much longer than the fibula and the shaft of the former bone is straight and is transversly expanded near the distal end as in *Meles*. The fibula is on the whole more nearly like that of the latter genus than that of the otter, while the astragalus strongly suggests that of *Gulo luscus* and has the astragalar foramen, a characteristic feature in *Meles*. The John Day form, *Oligobunis*, was regarded as an aberrant member of the *Canidæ* by Professor Cope, while Dr. Matthew (Bull. Amer. Mus., Vol. XXIII, p. 193, 1907) after the re-examination of the type, questions Cope's reference and transfers the genus to the *Mustelidæ*. After a comparison and careful study of the newly acquired material now in the Carnegie Museum

I fully agree with Matthew in the taxonomic position of *Oligobunis*. Furthermore it is quite evident that the present genus is closely related to the John Day form and quite likely in a direct line of descent which the generic name used implies. *Oligobunis lepidus* Matthew (*l. c.*, p. 194) is a connecting type; it is a smaller species than the John Day form, but indicates a type specialized differently from the present genus, having $M_{\overline{2}}$ very much less reduced, while $P_{\overline{1}}$ is more reduced than the same tooth in the present genus, indicating greater tendency towards the loss of one tooth and the retention of the other in *O. lepidus* than in *Paroligobunis simplicideus*. $M_{\overline{2}}$ in *O. lepidus* is one half the antero-posterior diameter of the carnassial, while that tooth in the present genus is only one third the antero-posterior diameter of the carnassial, plainly showing that in the present genus there is a more strongly marked advance toward modern forms.

Potamotherium (= *Stephanodon*) of Europe has a general resemblance to the new genus here proposed, but it is quite clear that this European form is at least generically different. In comparing the present type specimens with Dr. Schlosser's [28] figures, it is seen that $P_{\overline{1}}$ in the American form is smaller, the premolar series increases more in size, from before backward in the jaw, the metaconid of $M_{\overline{1}}$ is less developed and placed higher up on the crown, and the heel is smaller. Upon further comparison it is seen that the lower jaw is deeper and shorter in *Paroligobunis*. Of especial importance is the proportion of the hind limbs of the two genera. In *Potamotherium* the femur is shorter than the tibia, an aquatic feature, while in *Paroligobunis* the femur is longer than the tibia. The material at hand displays further comparison which may, however, be regarded as of less importance between these two genera; namely, the more strongly developed cingula and accessory tubercles of the premolars, and the external position of $P_{\overline{1}}$ in the European form, while in *Paroligobunis simplicidens* $P_{\overline{1}}$ is internal due to the reverse obliquity of $P_{\overline{2}}$ in the latter.

Paroligobunis (*Potamotherium*) *lacota* which was provisionally referred to the European genus by Matthew and Gidley [29] appears to be quite closely related to *Paroligobinus simplicidens* having apparently somewhat smaller canines and a slenderer jaw than the latter species. Dr. Matthew states (*l. c.*, p. 254) that Cope's type of *Potamotherium* (*Lutrictis*) *lycopotamicus* is lost and cannot be verified with Cope's reference, there being no illustrations of the type specimen.

Stenogale (*Potamotherium*) *robusta* Cope was based on a lower jaw containing part of the dentition and was found in the Upper Miocene near Fort Niobrara, Nebraska.

[28] Beitrage Paleontologie Osterich-Ungars und des Orients, Pl. VIII, figs. 18, 63, 64, 65, 1888.

[29] Bull. Amer. Mus. Nat. Hist., Vol. XX, p. 254, 1904.

Matthew and Gidley doubtfully referred this type to *Potamotherium*. As this American form now stands I cannot see that it is much nearer *Potamotherium* than *Stenogale* as the jaw is deeper in proportion; it is also somewhat shorter and more robust, the symphysis is lighter, the premolars are smaller and M_3 larger than in the former genus, while the latter genus has the under border of the lower jaw very much more curved fore-and-aft, the premolars are too large in proportion to the carnassial, the heel of the latter is entirely different in shape, and very much smaller, and the tubercles of the teeth are evidently sharper and higher than in the American specimen. The latter form should, I think, occupy a new generic position (~~*Brachy-gale*~~ Sthenictis) somewhat near the *Oligobunis* phylum although the premolars are proportionally smaller than in the latter, especially in the transverse diameter. In *Paroligobunis* the jaw is proportionally shorter and heavier, the alveolar border is more curved from before backward, the premolars are more crowded, and the carnassial has apparently a shorter heel than in the new genus here proposed.

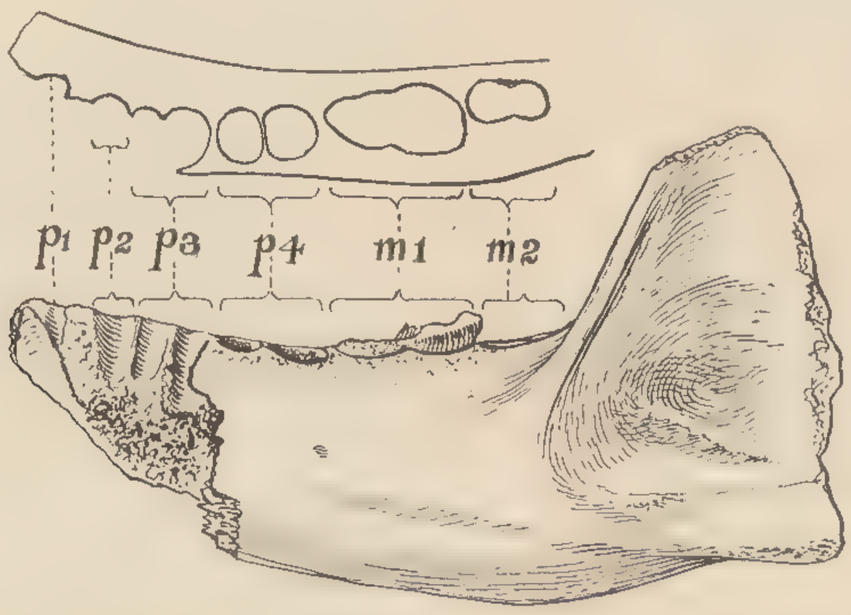


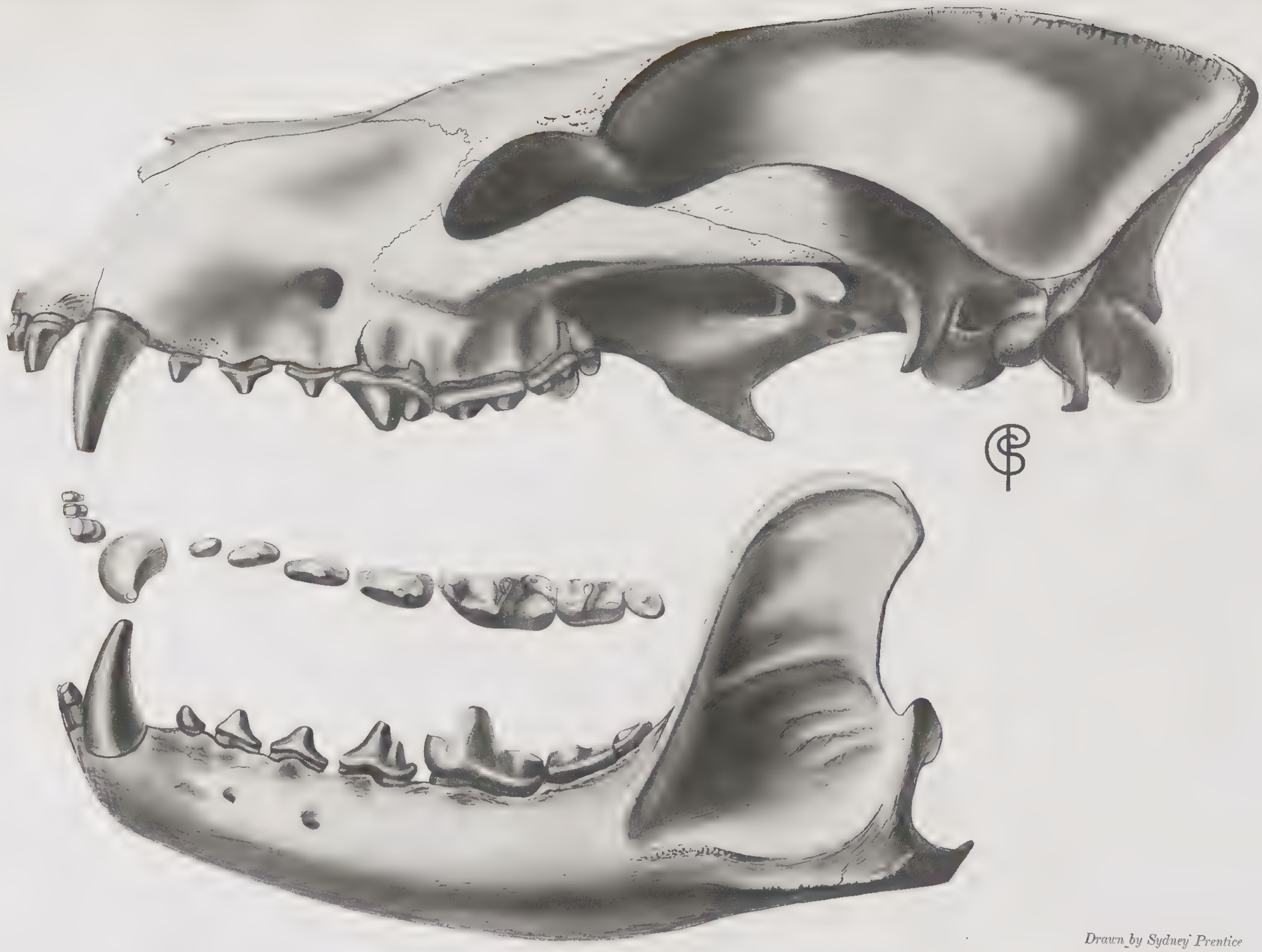
FIG. 69. Alveolar Border and External View of Jaw of *Brachypsalis pacycephalus* Cope. Nat. size. (Cope collection, No. 8544, Am. Mus. Natural History.)

Brachypsalis pachycephalus Cope was proposed (*l. c.*, p. 951) on a rather inadequate type, a left mandibular ramus, from the same locality in which *Stenogale robusta* was found. Professor Cope afterwards referred this type to *Potamotherium* of Europe, while Matthew and Gidley (*l. c.*, p. 254) accept the type as valid and distinct from *Potamotherium*. In a former paper[30] the present writer regarded *Paroligobunis* (*Brachypsalis*) *simplicidens* as possibly an ancestral form to *Brachypsalis*, a view which is no longer tenable inasmuch as the latter species has $M_{\overline{2}}$ proportionally larger, and the carnassial apparently smaller in proportion to the premolars. (Compare figs. 64 and 65 with fig. 69.)

[30] Ann. Carn. Mus., Vol. IV, p. 45, 1906.

Ælurocyon Peterson and *Megalictis* Matthew are more modified forms which, however, are apparently related to this group of the *Mustelidæ*. One of the chief generic differences between *Ælurocyon*, *Megalictis*, *Oligobunis*, and *Paroligobunis* is the presence of the metaconid on $M_{\overline{1}}$ of the two latter and the absence of it in the case of the two former genera. In *Paroligobunis* the metaconid is situated nearly as high up as the summit of the protoconid, and quite closely fused to the latter. Some of the Siwalik mustelids (*Melivoradon*) are also closely allied to this general group. I fully agree with Dr. Matthew's[31] statements that *Mellivora* and *Gulo* are the nearest living allies of *Ælurodon* and *Megalictis;* I would in fact also include *Oligobunis*, *Paroligobunis*, and possibly the proposed new genus ~~*Brachygale*~~ Sthenictis as not so very distantly related especially to *Ælurocyon* and *Megalictis*.

[31] Bull. Amer. Mus. Nat. Hist., Vol. XXIII, p. 204, 1907.



Drawn by Sydney Prentice

Daphœnodon superbus, TYPE. (No. 1589, C. M. CAT. FOSS. VERT.) VIEW OF LEFT SIDE OF SKULL AND CROWN VIEW OF LOWER DENTITION. NAT. SIZE.

Drawn by Sydney Prentice

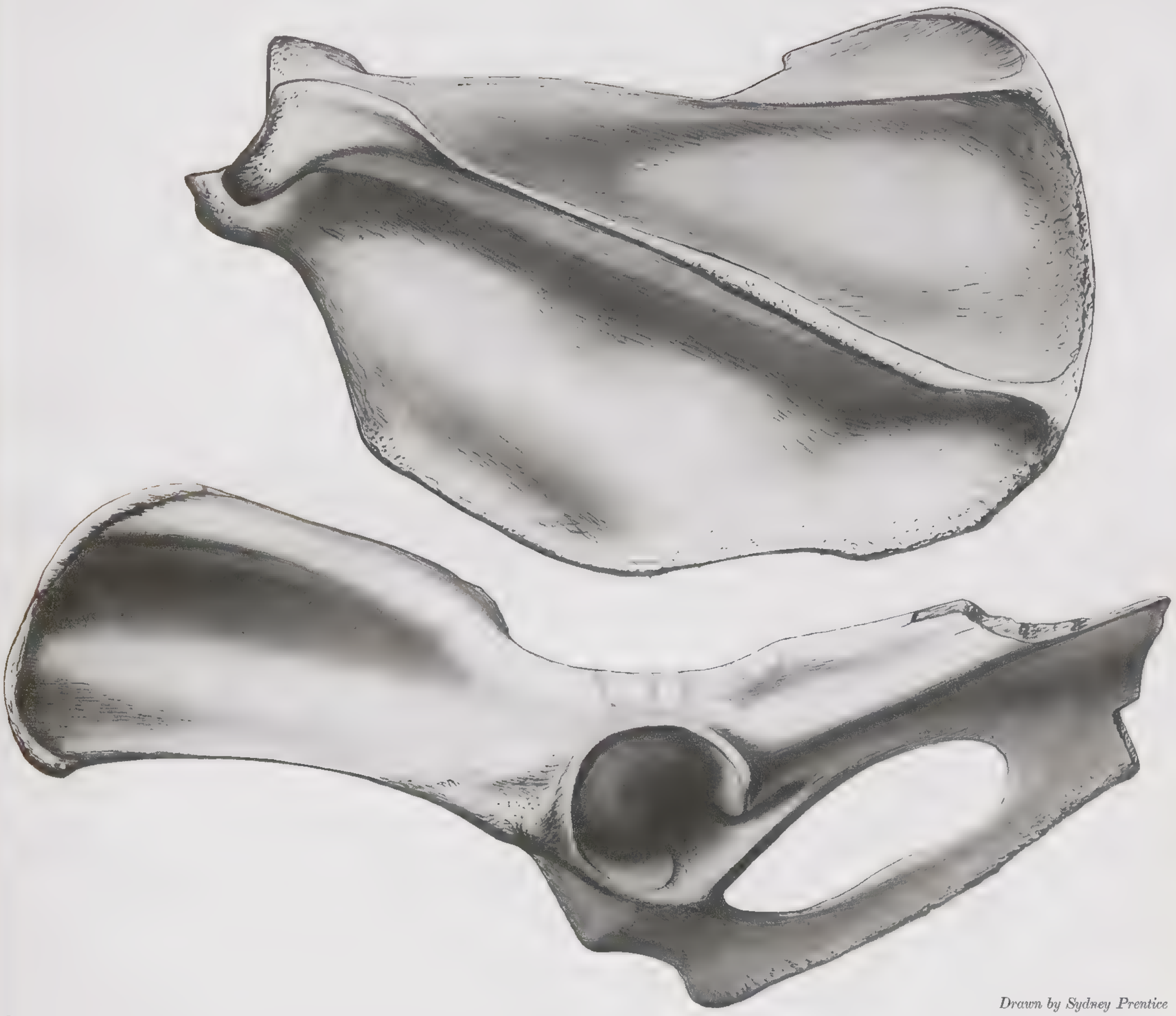
Daphœnodon superbus. TYPE. (No. 1589, C. M. CAT. VERT. FOSS.) PALATAL VIEW OF CRANIUM. NAT. SIZE.

Drawn by Sydney Prentice

Daphœnodon superbus. TYPE. (No. 1589, C. M. CAT. VERT. FOSS.) SUPERIOR VIEW OF CRANIUM. NAT. SIZE.

Drawn by Sydney Prentice

Daphœnodon superbus. TYPE. (No. 1589, C. M. CAT. VERT. FOSS.) ANTERIOR AND POSTERIOR VIEWS OF SKULL. NAT. SIZE.

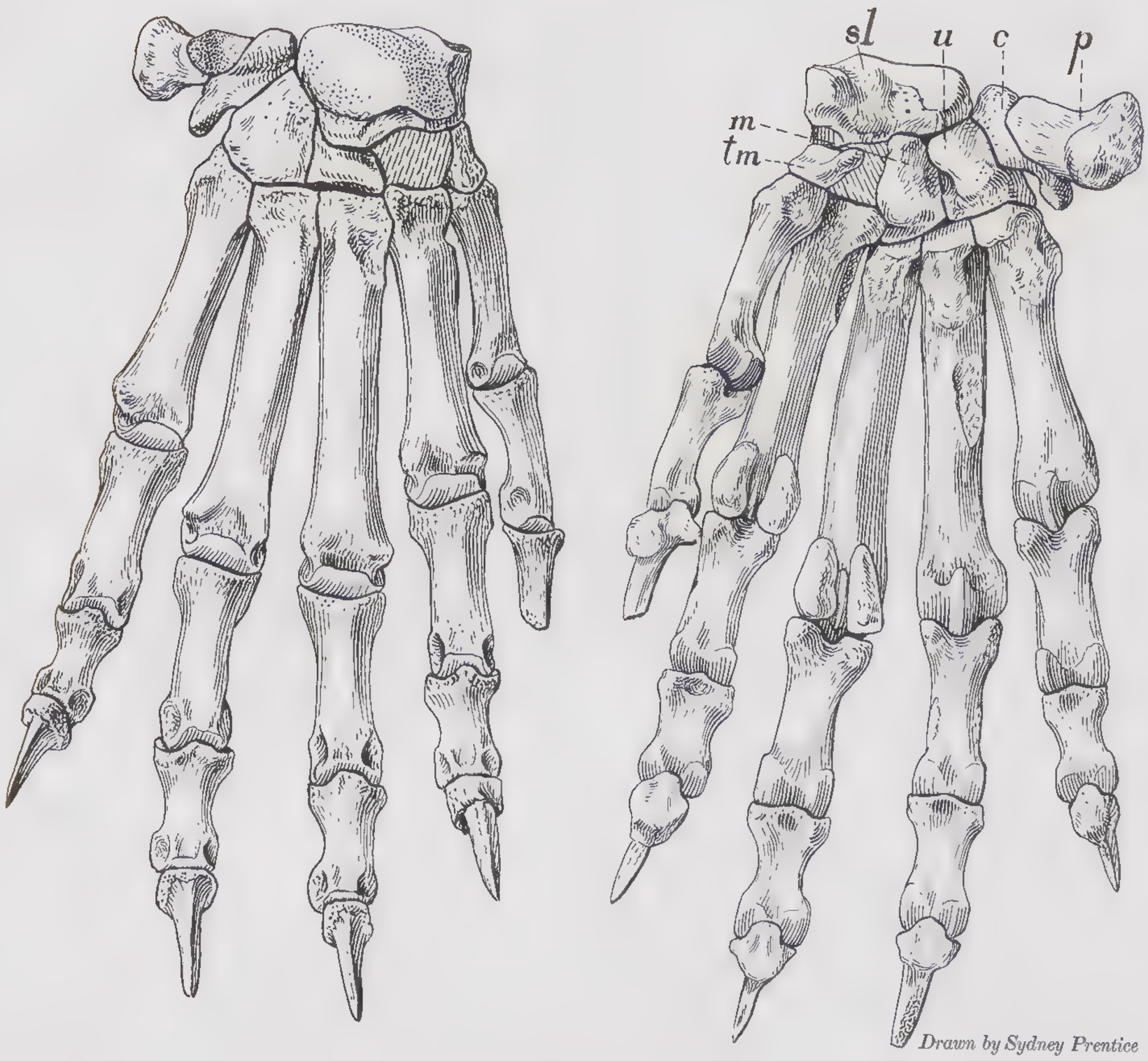


Drawn by Sydney Prentice

Daphœnodon superbus. EXTERNAL VIEW OF RIGHT SCAPULA (No. 1589, C. M. CAT. VERT. FOSS.) AND LEFT SIDE OF PELVIS. NAT. SIZE. (Note: the illustration of the pelvis is from a specimen in the collection of Amherst College.)

Drawn by Sydney Prentice

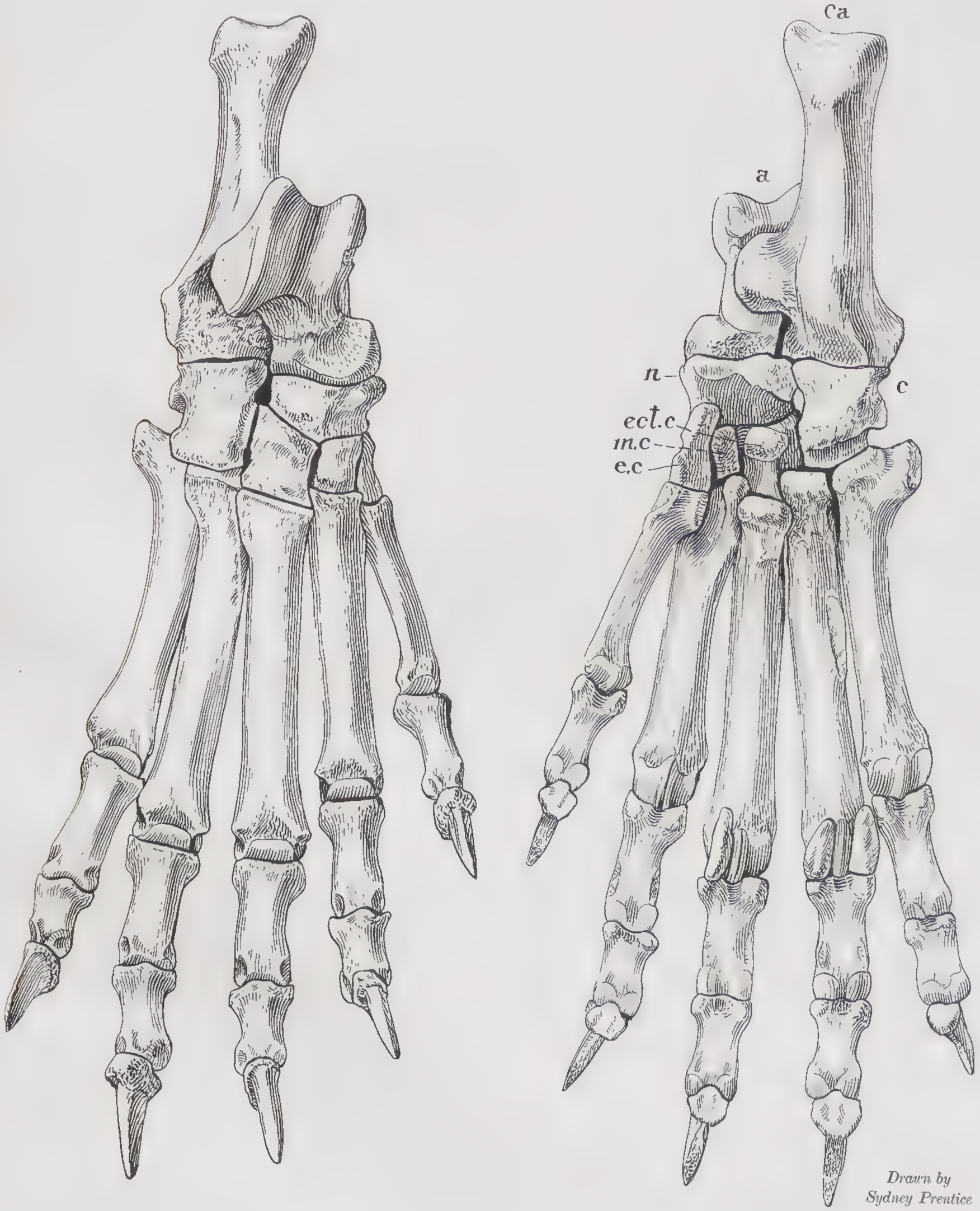
Daphœnodon superbus. TYPE. (No. 1589, C. M. CAT. VERT. FOSS.) 1, RADIAL VIEW OF HUMERUS OF RIGHT SIDE. 2, ANTERIOR VIEW OF HUMERUS OF RIGHT SIDE. 3, RADIAL VIEW OF RADIUS OF RIGHT SIDE. 4, ANTERIOR VIEW OF RADIUS OF RIGHT SIDE. 5, ULNAR VIEW OF ULNA OF RIGHT SIDE. 6, ANTERIOR VIEW OF ULNA OF RIGHT SIDE. ALL FIGURES NATURAL SIZE.



Daphænodon superbus. TYPE. (No. 1589, C. M. CAT. VERT. FOSS.) DORSAL AND PALMAR VIEWS OF RIGHT MANUS. NAT. SIZE. (The hoods of the ungual phalanges are more or less broken.)

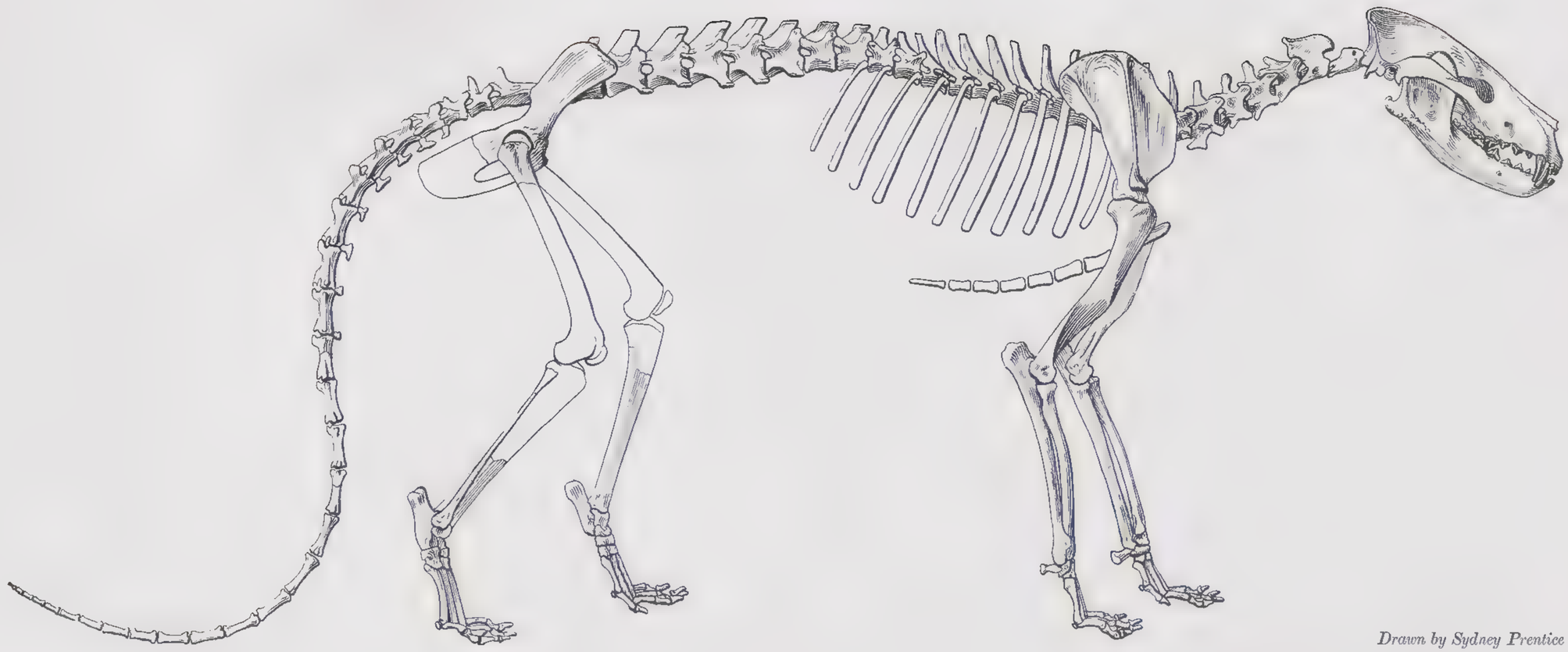
Drawn by Sydney Prentice

Daphœnodon superbus. TYPE. (No. 1589, C. M. CAT. VERT. FOSS.) 1, ANTERIOR VIEW OF LEFT FEMUR. 2, TIBIAL VIEW OF LEFT FEMUR. 3, ANTERIOR VIEW OF LEFT TIBIA. 4, FIBULAR VIEW OF LEFT FIBULA. 5, POSTERIOR VIEW OF LEFT FIBULA. ALL FIGURES NATURAL SIZE. (The illustrations of the femur are from a specimen in the collection of Amherst College.)



Drawn by
Sydney Prentice

Daphœnodon superbus. TYPE. (No. 1589, C. M. CAT. VERT. FOSS.) DORSAL AND PLANTAR VIEWS OF THE PES. NATURAL SIZE.



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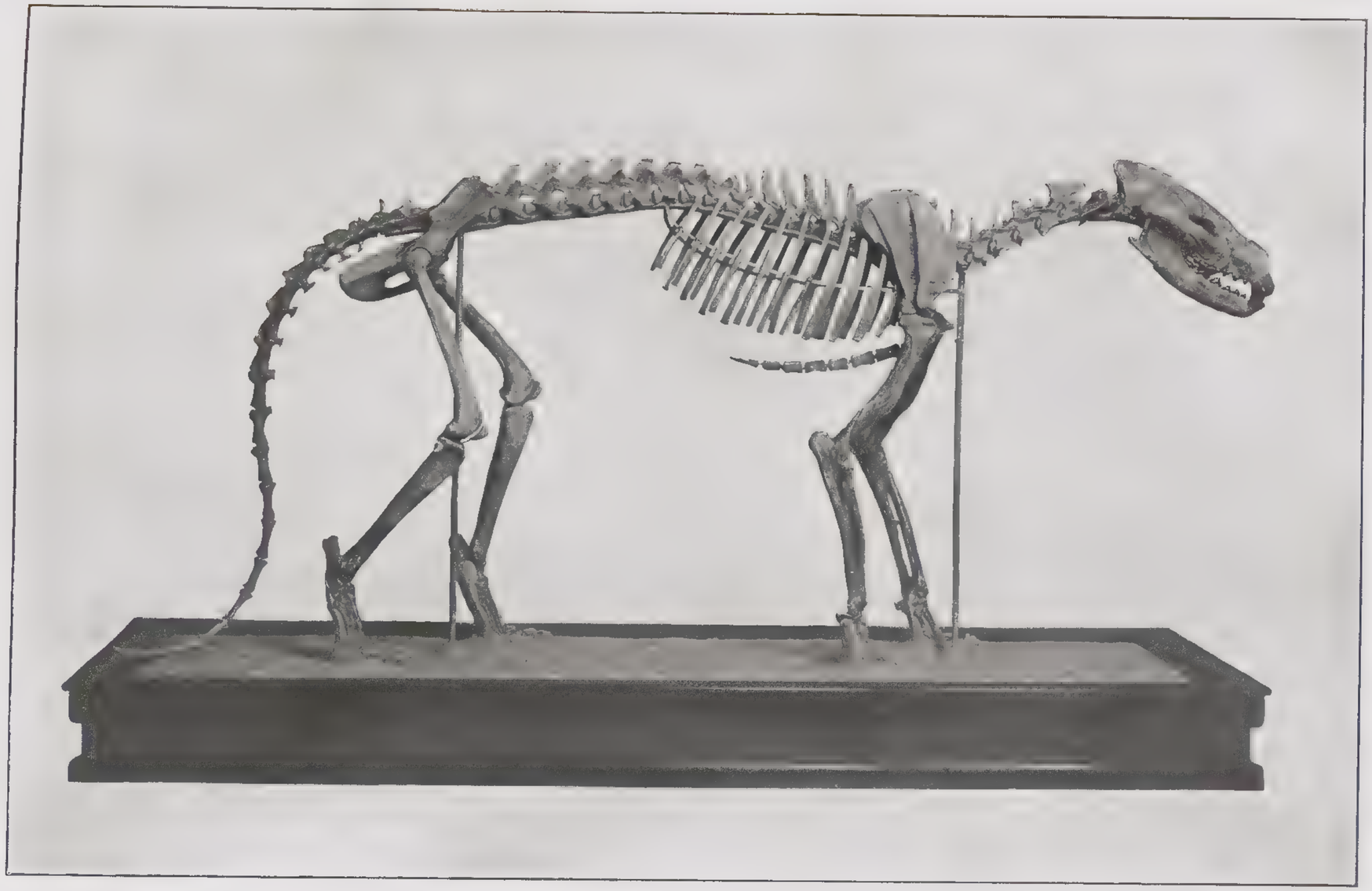

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GENERAL INTRODUCTION.

PART I. ANATOMICAL INVESTIGATIONS.
PART II. THE SYSTEM OF THE NORTH AMERICAN NAJADES.

BY A. E. ORTMANN, PH.D.

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OF THE

CARNEGIE MUSEUM.

VOL. IV. NO. 6.

A MONOGRAPH OF THE NAJADES OF PENNSYLVANIA.

By Arnold E. Ortmann, Ph.D.

GENERAL INTRODUCTION.

The writer began to collect *Najades* in Pennsylvania as early as 1904. Additional material was incidentally secured in 1905 and 1906, while he was hunting for crawfishes. In 1907 the collecting of mussels was systematically begun, and the particularly favorable seasons of 1908 and 1910, and in part also of 1909, permitted the taking of large numbers of species and specimens. Not only the shells but also the soft parts were collected, and the writer endeavored to find both males and females, the latter in the sterile as well as in the gravid state. In this he generally was successful, and a great quantity of material representing the soft parts was preserved in alcohol, partly with the shell, partly without, but always with the proper records. In this way a collection of the Pennsylvanian *Najades*, both of shells and soft parts, has been brought together, which certainly is superior to any other local collection; in fact, the writer believes that he has at his command a larger assemblage of the soft parts than is found in all other collections combined.

The chief purpose of this work was to secure the material for a systematic monograph of the *Najades* of our state. A preliminary list of the species found in Pennsylvania has been previously published (Ortmann, 1909), but since then, further information has been obtained with respect to the systematic and zoögeographical side of the subject, and in the present monograph a final account will be given. In addition, the writer has investigated the anatomical structure of the mussels, and very important structural features, chiefly in the gills, have been discovered, which had been in part entirely overlooked by previous authors. The knowledge of the anatomical details thus obtained has enabled the writer to revise

the system of the North American *Najades*, and to put it upon a more secure foundation. A preliminary account of this work has also been published (Ortmann, 1910).

The most prominent advance in our ideas as to the systematic arrangement of the fresh-water mussels is marked by the publication of Simpson's paper on the *Najades* (Simpson, 1900). We cannot but admire this work, for the general principles of classification are correctly recognized by Simpson, and the soundness of his views has been amply confirmed by our own investigations. Yet Simpson suffered under two serious disadvantages: he did not possess enough material representing the soft parts to settle all systematic questions, and did not make any microscopical investigation of the anatomical structures. This latter shortcoming has been in part remedied by Sterki (Sterki, 1903). In the present monograph additional observations will be furnished, and with regard to the Pennsylvanian species, it may be said that the soft parts of all of them, with very few exceptions, have been at hand, and they are now sufficiently well known to enable us to assign each species to its proper place in the system. Of course in the case of the species and genera not found in Pennsylvania, this reference remains to be made; but after the main points of view have been indicated, this will be a comparatively easy task. The fact, however, should be emphasized that there is now no excuse whatever for collectors of the *Najades* preserving only the hard parts, and throwing away the soft parts. The soft parts form an integral portion of the animal, and should be preserved and examined together with the hard parts, and this is most imperative in the case of those genera, of which our present knowledge is more or less defective.

The greater portion of the material at hand, forming part of the collections belonging to the Section of Invertebrate Zoölogy in the Carnegie Museum, was secured by the writer in person. The art of collecting mussels has to be learned, because, while it is easy enough to pick them up, it can only be done after a thorough knowledge of the proper places and seasons has been acquired. The *Najades* inhabiting our rivers, creeks, ponds, and lakes, can only be obtained alive by going after them into the water, but as soon as their whereabouts is discovered, it is easy enough to get them. Their discovery cannot be accomplished under all conditions. Part of the season our creeks and rivers have too much water, or the water is too muddy to locate the mussels. This is the case chiefly in early spring, when the snow melts, and in the first half of summer, the time of the copious summer rains.

In Pennsylvania the best season is generally from August to October, when

the water courses are low and clear; but very often there is also a season of low water from the end of April to the end of May. In smaller creeks, where the water is never very deep, any dry period of about a week's duration will bring about favorable conditions, but in the larger rivers successful collecting is generally possible only late in summer and in autumn. The exceptionally dry summers of 1908, 1910, and partly also of 1909, afforded unusual and unexpected facilities for making collections. Collecting in the lakes (Lake Erie for instance) does not depend so much on the season, but it depends a good deal on the weather. Quiet days, when there are no wind and surf, should be selected.

Hand-picking is the best way of securing specimens. Devices like the so-called "clam-dredge" of the mussel fishermen of the Mississippi and Ohio are useless in our rivers on account of the rough and rocky character of their bottoms. Yet in Lake Erie upon sandy and sandy-muddy bottoms I have used a similar apparatus to great advantage. This is a modification of the common "clam dredge," and I am especially indebted to Dr. W. J. Holland for suggestions in constructing

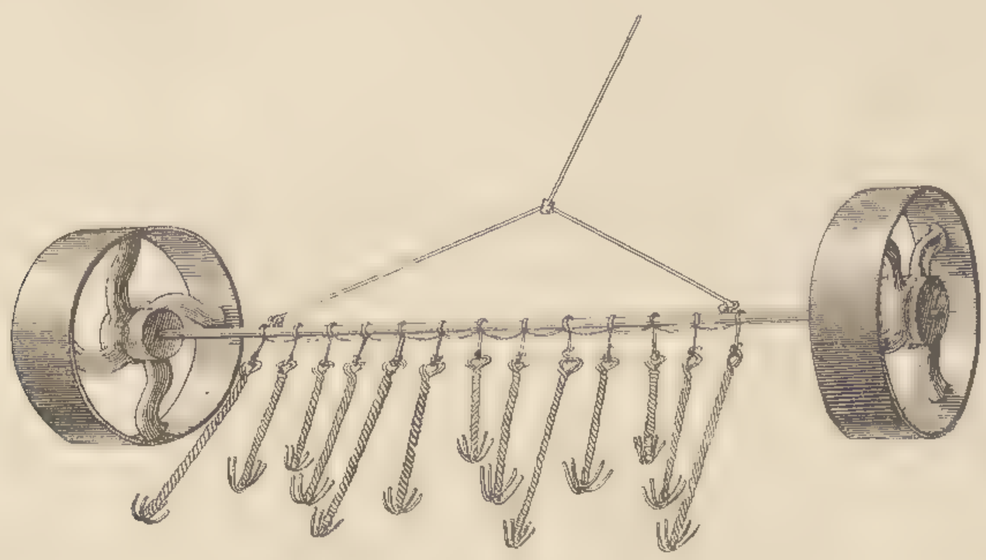

FIG. 1. The Holland Clam-dredge.

this device. It consists (See fig. 1) of a piece of gas-pipe with two wheels at the ends, to which four-pronged hooks are attached. The hooks are made of wire, with their stems rather *long* (six to ten inches), and they are tied to the gas pipe with *very short* strings: this prevents the tangling up of the whole mass, which is a great nuisance, when, as in the usual clam dredge, *short* hooks with *long* strings are used. With this apparatus, "*the Holland clam-dredge*," I obtained shells in Presque Isle Bay, Lake Erie, at depths of from six to fifteen feet.

In 1910 I had special advantages for collecting *Unionidæ* in Lake Erie, by being offered the opportunity to go out with the "sand-sucker" of the Erie Sand and Gravel Co. I thus obtained specimens at depths of from ten to fifteen feet.

I cannot close these introductory remarks without making public acknowledgment of the encouragement and valuable help furnished to me at all stages of my work by Dr. W. J. Holland, the Director of the Carnegie Museum. First of all, the study of the *Najades* forms part of Dr. Holland's general scheme and his policy of studying our local fauna (See Holland, W. J., in the Proceedings of the American Association of Museums, Vol. III, 1909, p. 12) and thus the general idea of this work, as well as my previous work on the crawfishes (See Memoirs of the Carnegie Museum, II, 1906), is largely due to his suggestion. In addition, he supplied me with the necessary means for carrying on my collecting, and the chief item in such work is the expense. As to this, I can only express my great gratification and sincere thanks for the liberal allotment of funds made to me. Finally, Dr. Holland furnished me with all the paraphernalia for the work of the laboratory, including everything that belongs to its literary and technical side. It goes without saying that he always followed the progress of my studies with the closest attention, helped me along in difficult cases, and was ever ready with suggestions and advice.

The wealth of the subject matter to be treated makes it necessary to divide this memoir into parts. Since it is absolutely essential to lay a proper foundation for the systematic part, and since the anatomical studies furnish this foundation, it is obvious, that the latter should be given first. In the present publication therefore I shall take up questions of anatomy and their bearing upon the system of the North American *Najades*. I reserve for a future publication the description of the various species and their zoögeography.

PART I. ANATOMICAL INVESTIGATIONS.

The anatomy of the European *Unionidæ* appears to be rather well known, at least after the fashion in which they are treated in the textbooks. (I have consulted those of Cooke, 1895, and of Taylor, 1894 and 1900.) We have also several accounts of the anatomy of American forms (for instance, Brooks, 1890). But looking more attentively at these, we find that comparatively few genera and species have been studied. This is not astonishing in the case of Europe, where only a few types are found. With reference to the American shells, however, it is very strange that we possess descriptions, more or less satisfactory, only of *Unio* and *Anodonta*, and only of eastern species of these genera. Further, we shall see that even in these some of the most important parts of the anatomy have been neglected.

With regard to the numerous other genera found in the great interior basin, we possess only scanty notes on the gross anatomy. These have been supplied

almost exclusively by Lea and Simpson. The latter in his great "Synopsis" (1900) gives generalized accounts of the soft parts, chiefly in the diagnoses of the higher groups, genera, and their subdivisions; but we often remain in doubt whether a particular species has been examined by Simpson or not. Simpson furnished descriptions of the soft parts of species for another publication (See Baker, 1898), but in this case it is to be observed that he sometimes described the soft parts of a species which he did not examine, or rather that he inferred some of the characters from other species, which he believed to be allied. *Quadrula coccinea* is an instance. The description of the marsupium is here positively incorrect and was introduced apparently in the belief that this species, being supposedly a *Quadrula*, should have the marsupium of this genus.

Nevertheless, Simpson's observations published in the "Synopsis," are of the highest value, for he correctly recognized the most essential part of the anatomy, namely the *marsupium*. In all *Unionidæ* (as in the *Najades* in general), the eggs are carried in the gills, where they develop into larvæ, known as *glochidia*. This is a well known fact; and it was also long ago known (chiefly through Lea) that the marsupium is formed in the different species by different gills, or parts of gills. But this character had never been employed in making a systematic arrangement, and the credit for recognizing the importance of the marsupium, and for using it successfully in the division of the *Unionidæ* into genera and in the grouping of the latter, distinctly belongs to Simpson.

But Simpson studied only the general features of the marsupium, and thus his groups are not in all cases without objection. Further in a number of species he did not succeed in ascertaining the shape of the marsupium, and thus was able to place them only tentatively. As has been said above, several well supported corrections have been introduced by Sterki (1903), who paid attention chiefly to the shape of the glochidium, together with that of the marsupium.

The present writer made it his chief purpose to ascertain the shape of the marsupium in all species which came under his observation, and to this end to obtain gravid females. In this undertaking he was generally successful, and, with very few exceptions, gravid females of all Pennsylvanian species were secured. But when he took up the closer anatomical study, he made a very important discovery, namely that *in all our Unionidæ the anatomical structure of the gills, which serve as marsupia, is permanently differentiated.* It was known and emphasized by Sterki that this is externally the case in a certain group of genera (*Lampsilis*-type), while it was maintained that in the rest no such differentiation was visible in the female, when not gravid. But this latter assumption is incorrect.

There is always in the female an anatomical difference in the marsupial gills, and this difference may be detected even without a microscopical investigation, although the latter is generally advisable in order to render the structure absolutely clear.

In addition the writer has found, chiefly along the edge of the mantle, a number of structural differences which are also important, and will be described below.

A. General Structure of the Gills.

The primary elements of the gills are the *gill-filaments* (*gill-tentacles* of Brooks) —cylindrical or somewhat compressed tubes, which arise in two longitudinal rows from a common base (ctenidium) between the foot and the mantle of the mussel, and hang down into the branchial chamber. These filaments are doubled back upon themselves, the outer row outwardly, the inner inwardly. The filaments of each row being connected with each other (See below), there are thus *two gills* on each side of the animal, an *inner* and an *outer* one, each consisting of two *laminæ* (*lamellæ*) composed of filaments, the laminæ including between them a space. The two laminæ are distinguished as the *primary* and the *secondary* limb of the gill, the former being the descending adaxial part, the latter the reflected and ascending part. The latter part is the outer lamina in the outer, and the inner lamina in the inner gill.

On the inside of each lamina, toward the cavity of the gill, there develops a peculiar tissue, called *interlamellar outgrowth* (Taylor, p. 177). This connects the gill-filaments of each lamella, leaving more or less regularly placed open holes (*ostia*), by which the inner cavity of the gill communicates with the outside. This interlamellar tissue forms a rather large part of the gill, in fact the lamella itself appears composed chiefly of this tissue, while the original gill-filaments form only its outer layer, separated from one another by the *intertentacular* (Brooks) or *interfilamentar grooves*. The interlamellar tissue is permeated by lacunar blood-vessels. The filaments develop along their sides *chitinous rods* for the support of the gill. Two such rods belong to each filament, but these rods are not continuous, but interrupted, consisting of longer or shorter, disjointed pieces.

The filaments and their chitinous rods run about vertically, that is to say, from the base toward the edge of the gill; a slightly fan-shaped arrangement is sometimes indicated, corresponding to the curved edge of the gill, upon which they stand vertically.

The interlamellar cavity of each gill is not simple, but is divided. There are "interlamellar partitions" (Brooks) or "interlamellar junctions" (Taylor), which connect the two laminæ of the gill. In most cases, these connections are developed

as *septa*, dividing the inner cavity of the gill. They run about parallel to the gill-filaments, that is to say, vertically toward the edge of the gill, and consist of a tissue similar to that of the interlamellar outgrowth, with differences which will be described below. Most of these septa run continuously all the way from the base to the edge of the gill, while others are shorter, and are intercalated at various distances from the base, but each septum is always continued to the edge. Thus the interlamellar cavity is divided into a number of canals, running from base to edge, which are called *water-tubes*. The size of these water-tubes is variable, and differs considerably according to sex (See below).

There is one exception among the *Najades* known to me from North America, which does not show this arrangement, *Margaritana margaritifera*.[1] Here the gills are also composed of filaments and possess an interlamellar outgrowth, which, however, is rather slightly and irregularly developed. *But there are no septa dividing the cavity of the gills.* Instead of this, the two laminæ are connected by more or less cylindrical or irregular thickenings of the interlamellar outgrowth, which are rather heavy and solid, and are placed quite irregularly. Sometimes these connections are a little elongated in the direction of the filaments, but they never are continuous septa, but rather patches of tissue, and if any regularity is observable, it is a somewhat *diagonal* or *oblique* arrangement. Toward the edge of the gill, and in its hindmost part a vertical arrangement is indicated, but even here there are no complete septa, and consequently no *water-tubes* (See fig. 2).

FIG. 2. *Margaritana margaritifera* (L.); right gills spread out and seen from below, showing arrangement of interlamellar connections.

This peculiar development of the interlamellar junctions in *Margaritana* is in my opinion very important. While the presence of water-tubes is a character common to all our other *Najades*, the absence of this feature in *Margaritana* is very remarkable, and I have no doubt that this character, together with the otherwise slight development of the interlamellar outgrowth, which gives to the primary gill-filaments a greater significance in the whole make-up of the gill, points to *a more primitive stage* in the development of the gill in *Margaritana*, than in any other mussel.

The secondary limb of each gill (outer in the outer, inner in the inner gill)

[1]In quoting species, I shall, for the present, use Simpson's nomenclature.

extends upward as far as the base of the primary limb. Its distal margin in the outer gill is fused with the mantle, and thus a small space is cut off from the branchial chamber, which appears as a longitudinal canal along the base of the outer gill—the *suprabranchial* or *cloacal canal* of the outer gill, into which the water-tubes of this gill open. In the case of the inner gill, the secondary (inner) lamella is always connected anteriorly with the wall of the visceral mass (abdominal sac) for a shorter or longer distance; behind this connection it is sometimes free as far as the posterior end of the foot; and behind this point, the two inner laminæ of the right and left inner gill are connected with each other up to the posterior end. Thus the inner gill also has a *suprabranchial* or *cloacal canal,* which is double (right and left) anteriorly, lying on either side of the foot and abdominal sac, but becomes united back of the foot into one cavity. In many cases this canal is not entirely closed, but communicates with the branchial chamber through a slit along the sides of the abdominal sac.

There are a number of variations in the development of the characters mentioned in the last paragraph.

The outer lamina of the outer gill is united with the mantle up to the posterior end of the gill in practically all species known to me, the only exception being in the case of *Margaritana margaritifera.* Here (Compare fig. 6) the outer lamella is free posteriorly for a considerable distance, and the posterior end of the gills assumes in consequence a very peculiar shape (See below, under "diaphragm").

As has been stated, the connection of the inner limb of the inner gill with the abdominal sac is variable. In the most primitive condition, such a connection is present only at the anterior end of the gill for a short distance, and in this case the inner lamina is free and leaves a slit-like communication open between the suprabranchial canal and the branchial chamber. In other forms, this slit is more or less, often entirely, closed; and then the whole inner lamina of the inner gill is connected, first to the abdominal sac, and farther behind, back of the hind end of the foot with that of the gill of the other side, and thus the suprabranchial canal of the inner gill is entirely separated from the branchial chamber.

Long ago Louis Agassiz called attention to these differences of structure. Later on their value was doubted by Lea as well as by Simpson, and Sterki also does not consider them as of much systematic significance. I have investigated my material with reference to this question, and find that the connection of the inner lamina of the inner gill with the abdominal sac is indeed variable, and that sometimes it is differently developed in the same individual on the right and left side. *But it is only in certain forms that this variability occurs.* In others this character is quite

constant. Thus in the species placed by Simpson in the genera *Quadrula*, *Pleurobema*, *Unio*, *Margaritana*, *Symphynota*, *Anodontoides*, and *Anodonta*, I always found the inner lamina of the inner gill entirely free from the abdominal sac, with the exception of its anterior end. This is the more remarkable, since both Lea and Simpson (See Simpson, 1900, p. 766, footnote 2) affirm that in *Quadrula multiplicata*, a species which stands near our *Q. undulata*, the inner gills are sometimes free, sometimes connected. I have not seen that particular species; but of *Q. undulata* I have examined some thirty specimens, and have never seen a connected inner gill. Although the number of specimens investigated in this case seems small, the fact that I never found a connected inner gill in the genera named above, is, I think, rather significant, for I have looked over about four hundred individuals belonging to these genera, and it would be very strange, if variations occur here at all, that I by a curious chance never came across a single one.

Further, I found the inner lamina of the inner gill always almost entirely free in the following species of other genera: *Alasmidonta heterodon* (fifteen specimens investigated) *Lampsilis parva* (three specimens). In *Obliquaria reflexa* (four specimens) the gill is also free, but for a shorter distance, a little more than half of the abdominal sac. The same is the case in *Plagiola securis* (six specimens), where the length of the free edge is somewhat variable (in one case the slit was very short, but only on one side!).

On the other hand there are forms, in which the inner limb of the inner gill is always entirely united to the abdominal sac. This is the case in the genus *Alasmidonta* (excluding *A. heterodon*), in *Obovaria ellipsis*, *circulus*, and *retusa*, in the genus *Truncilla*, and in many species of the genus *Lampsilis* (*gracilis*, *alata*, *recta*, *orbiculata*, *ligamentina*, *radiata*, *luteola*).

In all those not hitherto mentioned, there is variation in this respect. This is most evident in the genera *Strophitus* and *Ptychobranchus*. In fact in the latter genus I have observed all conditions, from an inner lamina almost entirely free to an inner lamina entirely connected. In *Strophitus* it varies from free for about half the length of the abdominal sac to entirely connected. In *Plagiola elegans* (two specimens) the open slit was in one case short, about one fourth of the length of the abdominal sac, and in the other there was only a small hole at the posterior end of the foot. In *Lampsilis iris*, *nasuta*, *multiradiata*, *cariosa*, *ventricosa*, and *ovata*, the inner gill is entirely connected, or has a small hole at the posterior extremity of the foot; and in *Micromya fabalis* (four specimens), the slit is short, from about one fourth to one half of the length of the abdomen.

The closing of the slit proceeds always in an antero-posterior direction, and

if there is only a small opening left, this is never placed anteriorly, but always at the posterior end of the foot.

According to these observations, I must attribute to this character a certain limited systematic value. There are a number of forms, in which the primitive condition of an unconnected, free inner lamina of the inner gill is always found. There are other forms, which belong to the more advanced types, in which this lamina is always entirely, or almost entirely, connected with the abdominal sac. Between these stand others, in which all transitional conditions are found, and in some of these an intermediate condition seems to be characteristic, while in others this character is variable.

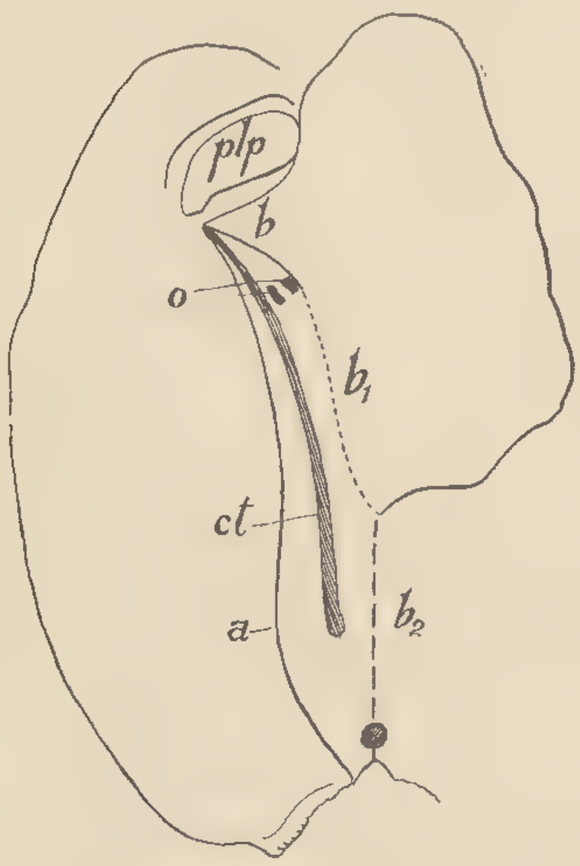

FIG. 3. *Anodonta grandis gigantea* (Lea) Left half of body, seen from below, with gills removed; showing attachment of gills.—*plp*, palpus; *ct*, ctenidium (base of gills); *a*, line attachment of outer lamina of outer gill to mantle; *b*, attachment of inner lamina of inner gill to abdominal sac; b_1, free edge of the latter; b_2, line of connection of the two inner laminæ of right and left gill; *o*, sexual and renal orifices.

As has been mentioned above, posteriorly to the abdominal sac and foot, the inner laminæ of the two inner gills unite in the median line of the body (See fig. 3). By this union, together with the connection of the outer laminæ of the outer gills with the mantle, a complete separation of the branchial chamber from the posterior part of the suprabranchial canals (cloacal chamber) is effected by a septum or *diaphragm*, which forms a horizontal division, from which the gills hang down (See fig. 4). At the posterior end the four suprabranchial canals of the two gills of the right and left side are united into one cavity, the *cloacal chamber*. This is brought about by the fact that the gills extend posteriorly beyond their attachment to the body at their base, or rather, that this attachment (ctenidium) does not extend to the posterior end of the body (See fig. 5). This attachment, the common base of the two primary limbs of the gills on each side, runs backward to a point, which generally lies about midway between the posterior end of the foot and the posterior margin of the mantle; beyond this point the inner limbs of the two gills on each side remain connected with each other, but are no longer attached to the body, and the two suprabranchial canals on each side are fused (See figs. 3 and 5). Thus of the four suprabranchial canals present in the anterior part of the body, each of which belongs to one gill, the two median canals are united first immediately behind the

posterior end of the foot; and a little bit farther back, the two outer canals (belonging to the outer gills) open into and unite with this cloacal chamber.[2]

In a posterior view (See fig. 4) the diaphragm separating the branchial and cloacal openings forms a rather short, simple, horizontal bridge, from which the gills hang down. Sometimes there is a slight median incision, when the two inner laminæ of the inner gills are not fully united to their ends, but according to my investigations this has no systematic value.

FIG. 4. *Anodonta grandis gigantea* (Lea). Posterior view, showing branchial, anal, and supra-anal openings, diaphragm, and posterior ends of gills.

We are to note an exception to the normal structure, and this is again *Margaritana margaritifera*. Here (See fig. 6) the diaphragm represents an entirely different aspect, which is due to the fact that, as we have seen above, the outer laminæ of the outer gills are not connected with the mantle up to their ends. Thus on the one hand the outer attachment of the diaphragm is not seen at the outer edge of the mantle, and the outer laminæ of the outer gills are free for a considerable distance, which causes the whole diaphragm to appear as if it were tapering to a median point; and, on the other hand, the cloacal opening (anal siphon) is much larger than usual.

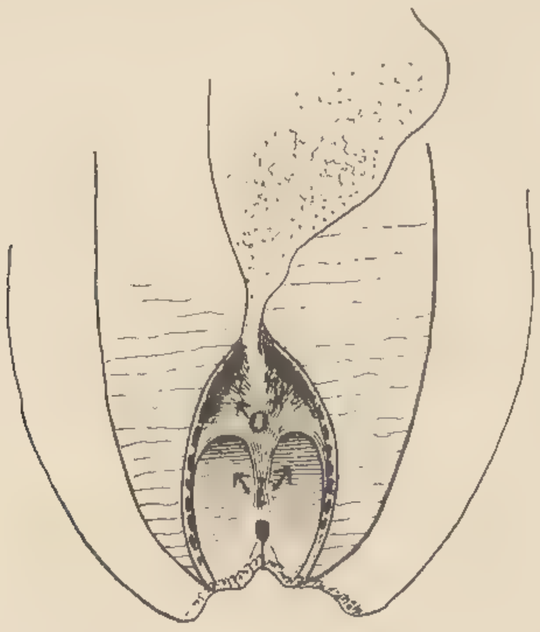

FIG. 5. *Anodonta grandis gigantea* (Lea). Posterior end of body, seen from below, with the diaphragm cut open in the median line, to show cloacal chamber.—*o*, openings of the suprabranchial canals of inner gills; *i*, openings of the suprabranchial canals of outer gills.

FIG. 6. *Margaritana margaritifera* (L.). Posterior view, showing branchial and anal openings, and the peculiar, incomplete diaphragm. No supra-anal is separated from the anal.

[2]This condition is not clearly represented in Brooks' (1890, p. 275, fig. 143) diagrammatic figure. The openings of the suprabranchial canals of the outer gills into the common posterior cloacal cavity are not shown. Their position would be indicated by the two nervous strands starting from the parietosplanchnic ganglia and curving backward toward the posterior end of the gills.

B. Structural Features of the Finer Anatomy of the Gills.

1. *The Water-tubes and the Septa dividing them.*

The following description of the water-tubes necessarily leaves out of consideration the peculiar form, *Margaritana margaritifera*, for this has no water-tubes.

We have seen above that the water-tubes are formed by the interlamellar junctions, which run from near the base of the gill to its edge, and are generally developed in the shape of continuous septa, which do not differ in their tissue from that of the interlamellar outgrowth, that is to say, in their normal development their tissue is lacunar, often containing blood-vessels (See Pl. LXXXVI, figs. 1, 5, 6*a*, 7*a*, 10*a*, 12*a*, 13, 14*a*, and Pl. LXXXVII, figs. 1, 4, 8).

This simplest structure is always found in both gills of the *male*, and there is no further differentiation of it in this sex, with the exception that toward the base of the gills the septa become sometimes a little more independent, being wider on account of the greater distance of the two laminæ from each other. The water-tubes formed by these septa are rather wide in the longitudinal direction of the gill, since the septa are distant from each other. The distances are variable, and often, chiefly so in the genera *Alasmidonta*, *Strophitus*, *Symphynota*, *Anodontoides*, and *Anodonta*, they are rather large near the base of the gill, where also the septa become irregular, running for a short distance diagonally, and being sometimes somewhat reticulate. In the genera just named there are often as many as forty and even more filaments between two septa. The average is from about fifteen to thirty; in other genera, the average is from about ten to twenty or twenty-five, although there is occasionally a larger or smaller number present. We may say, that normally there are more than fifteen filaments between two septa.

The identical structure is found in those gills of the female, which do *not* serve as marsupia, that is to say, in the inner gill, when the outer gill alone is used as a marsupium, and in the inner and the anterior part of the outer gill, when only the posterior part of the outer gill is so used (See Pl. LXXXVI, figs. 6*a*, 7*a*, 10*a*, 11*a*, 12*a*, 14*a*; Pl. LXXXVII, fig. 5). In those forms (genus *Quadrula*), where both gills serve as marsupia, this structure is not found at all in the female. (See Pl. LXXXVI, figs. 2, 4.)

In the marsupial gills of the female important structural modifications take place, and these modifications, which we shall describe presently, are quite marked, and invariably characterize the female sex. Consequently it is possible *not only to distinguish a sterile female (with the marsupium not charged) from a male, but also to discover the general character of the marsupium in a sterile female.*

In the *sterile female* the septa separating the water-tubes in the marsupial gill (See Pl. LXXXVI, figs. 2, 4, 7*b*, 10*b*, 14*b*; Pl. LXXXVII, figs. 2, 6, 7, 9) are much more *crowded* than in the male. There are, on an average, only from about five to ten filaments between two septa, although in some cases this number may increase to twenty. But in every species this number is considerably smaller in the female than in the male. This difference is very striking, and may be detected by the naked eye on holding up the gill toward the light. When I was hunting for sterile females among my material I always used this method in discovering the sex, and the much more crowded septa in the gill examined always indicated the female sex. I never made a mistake, and a specimen selected as a sterile female according to this test always proved to belong to this sex, when a closer microscopical examination was made.

In consequence of the more crowded condition of the septa the water-tubes have a different cross-section and are not elongated in the longitudinal direction of the gills, as those of the male, but are either more rounded or square (See Pl. LXXXVI, figs. 10, 14; Pl. LXXXVII, figs. 2, 9), or even elongated in the transverse direction (See Pl. LXXXVI, fig. 7).

But not only does the more crowded character of the septa indicate a marsupial gill, but *the septa themselves have a different structure.* While in the male and the non-marsupial gill of the female the septa are not much different from the interlamellar outgrowth, in the marsupial gill they are considerably altered. They are more strongly developed, appear more as independent structures, and their tissue is more compact, without lacunæ or blood-vessels. Generally, they are thicker, and also longer in the direction from lamina to lamina, and, what is their most striking character, their epithelial layer is quite different. While in the male type, described above, the epithelium, which faces the water-tubes, is a simple layer, in the marsupial gill of the sterile female *it is folded and thrown up into wrinkles,* which often assume considerable proportions (Compare Pl. LXXXVI, figs. 1 and 2, 7*a* and 7*b*; and Pl. LXXXVII, figs. 1 and 2, 8 and 9).

There is no question that this peculiar structure of the septa of the marsupial gills is an adaptation to their function. When the marsupium in the breeding season becomes charged with eggs, these gills naturally must swell, and they actually do so, as is well known. The swelling can be only in one direction, namely transversely to the longitudinal plane of the gill, that is, in the direction from lamina to lamina. This means, that the two laminæ of the gill are forced apart, and since they are connected by the septa, the latter, if they are not to be torn, must be built accordingly. The description and the figures given here of the

structure of these septa show that the latter is highly favorable to stretching, and while they stretch out, they become thinner, and the folds of the epithelium become smoothened and flattened (Compare Pl. LXXXVI, figs. 2 and 3, 8 and 9, 14 and 15; and Pl. LXXXVII, figs. 2 and 3). After the discharge of the mature embryos (glochidia) the gill and its septa assume again their normal shape.

This structural feature of the marsupial gill of the female is met with in all our *Unionidæ,* and in some it is the only one found. To the latter belong the following genera of Simpson: *Quadrula, Pleurobema, Unio,* and *Tritogonia.* But among these we observe a division into two groups. In some both gills, inner and outer, have the structure of marsupial gills, and become charged with eggs in the breeding season (See Pl. LXXXVI, figs. 2, 3, 4); in others it is only the outer gill which serves this purpose (See Pl. LXXXVI, figs. 6, 7, 10, 11, 12, 14). According to my investigations, in the following species *both gills* are marsupial: *Quadrula subrotunda* (Lea); *Q. kirtlandiana* (Lea); *Q. rubiginosa* (Lea); *Q. trigona* (Lea); *Q. pustulosa* (Lea); *Q. lachrymosa* (Lea) (according to material from Kansas); *Q. metanevra* (Rafinesque); *Q. cylindrica* (Say); *Q. undulata* (Barnes); *Q. hippopæa* (Lea); *Tritogonia tuberculata* (Barnes).

Only the *outer gills* serve as marsupia in: *Quadrula tuberculata* (Rafinesque); *Q. pyramidata* (Lea); *Q. obliqua* (Lamarck); *Q. coccinea* (Conrad); *Q. cooperiana* (Lea); *Pleurobema æsopus* (Green); *P. clava* (Lamarck); *Unio crassidens* Lamarck; *U. gibbosus* Barnes; *U. complanatus* (Dillwyn); *U. productus* Conrad.

The bearing of these facts upon the systematic arrangement will be discussed later.

There are *further structural modifications of the water-tubes* found in an association of forms of *Unionidæ,* which apparently compose a natural group, and have been already recognized as such by Sterki. This group is composed of the genera *Anodonta, Anodontoides, Symphynota, Strophitus,* and *Alasmidonta* of Simpson's "Synopsis." Of these I have investigated the following species: *Anodonta cataracta* Say; *A. grandis* Say; *A. imbecillis* Say; *Anodontoides ferussacianus* (Lea) (and var. *subcylindraceus* (Lea)); *Symphynota compressa* Lea; *S. viridis* (Conrad); *S. costata* (Rafinesque); *S. complanata* (Barnes); *Strophitus edentulus* (Say); *Alasmidonta undulata* (Say); *Alasmidonta marginata* (Say) (and the var. *varicosa* (Lamarck)); *A. heterodon* (Lea).[3]

[3]The existence of the structures described in the following paragraphs has been denied by Lefevre and Curtis (1910). As I have pointed out, however, (Ortmann, 1910a), their own figures show them. These lateral water-tubes cannot be blood-vessels, for which they apparently have been taken by these two authors, and this is so easily seen (even macroscopically) that we do not need to discuss it any further.

In all these only the outer gill serves as a marsupium, and during the breeding season, and only during this time, *each water-tube is divided into three tubes* running from the base to the edge of the gill, the division being effected by two secondary septa, which grow out at right angles from the primary septa (or interlamellar junctions). Two of these secondary water-tubes are located toward the faces (laminæ) of the gill, while the third one, which is much larger than the lateral ones, occupies the middle, and is separated from the two laminæ by the lateral tubes. *Only this central tube contains ova and embryos*, and properly should be called an *ovisac* (See the cross-sections, Pl. LXXXVI, figs. 8, 9, 11*b*, 16). Thus we see that, while in the forms discussed above the whole water-tube assumes the function of an ovisac, in the present cases *only a part of the original water-tube* discharges this function.

In addition, these ovisacs of the *Anodonta*-group are also *closed above, at the base of the gill*, by a similar tissue growing out from the septa at their lower ends (See Pl. LXXXVIII, figs. 3*a*, 11). As far as I can see, this tissue, which forms the ovisacs here, is furnished by, and forms part of, the epithelial layer of the septa.

This structure apparently is an adaptation to the lengthened breeding season and the extreme swelling of the marsupium, which is observed in these forms, and serves for the aëration of the mass of embryos. The swelling of the marsupium during the breeding season is very great here, much greater than in any of the forms belonging to the *Quadrula*-group. Thus it might become difficult to furnish the necessary oxygen to the developing eggs in the ordinary way, by the minute ostia perforating the laminæ, and the cutting off of a part of each water-tube close to each lamina must have the effect of keeping up a lively current of water within the gill, between the laminæ and the central ovisac.

As has been said, this threefold division of the tubes is present *only during the breeding season*. I have examined numerous sterile females, in which this structure is not seen (Pl. LXXXVI, fig. 15); in others it is indicated (Pl LXXXVI, figs. 7*b*, 12*b*) by a stronger fold (or group of folds) of the epithelial layer of the septa, near their insertion into the laminæ. In specimens where the eggs begin to go into the gills, this structure is sometimes not yet developed, but it appears soon, and the epithelial folds, which form the secondary septa within the water-tubes, begin to grow into the lumen of the water-tubes, and the folds of the opposing faces of the two septa finally unite in the middle. The point of union (cross-section of the line of union) is often distinctly seen in sections. After the discharge of the glochidia these structures disappear rapidly. I have seen them still present in some specimens, from which the embryos had recently been discharged

(Pl. LXXXVI, fig. 12*b*); in others they were greatly reduced, and the septa had assumed their normal shape; but in specimens of this group, where the marsupium was well filled with eggs or embryos, I have always seen them, although it is sometimes hard to obtain good slides, especially when the embryos have reached the glochidium-stage, since at that time the making of sections is rather difficult.

There is one form among those above enumerated, in which the development of this structure goes a step further. This is *Strophitus*. It was known long ago that this genus is characterized by a peculiar arrangement of the ova in the gills, they forming short, horizontal rows, which run transversely from lamina to lamina. According to my investigations this arrangement is brought about by further outgrowths of the epithelial layers of the septa, which fill the spaces between two septa, or rather only the middle part, the ovisac (See Pl. LXXXVIII, figs. 7, 8, 9), and thus the simple ovisac of *Anodonta* and other genera is here divided into a number of smaller, *secondary ovisacs*, running transversely across the gill, each of which contains a short, more or less cylindrical mass of eggs or embryos. These masses (placentulæ) will be discussed later. Also in *Strophitus* these structures are not present in sterile females, and after the discharge of the glochidia they soon disappear. The gradual development is seen in the vertical longitudinal sections of the marsupial gill on Pl. LXXXVIII, figs. 6 to 9.

All other forms of *Unionidæ*, which have not thus far been mentioned, have the simple structure of the marsupial gills, as described in the case of *Quadrula*, etc., but there are other differentiating structural features on the edges of the gills, which must be compared with the more primitive forms.

2. *Differentiating Structures on the edge of the gills.*

There is a difference in the structure of the edge of the inner and the outer gill, which is found in all our *Najades*, including *Margaritana*, and of this I shall first speak.

Making vertical cross-sections through the gills of a male (See Pl. LXXXVII, figs. 11, 12, 15; Pl. LXXXVIII, fig. 12), we observe that the edge of the outer gill is simply rounded off, while that of the inner gill possesses a peculiar longitudinal *furrow* along it, which may also be distinctly seen macroscopically. As to the meaning of this furrow, I can not make any suggestion, and am only able to state the fact of its presence. *By the presence of this furrow an inner may always be distinguished from an outer gill.*

The same difference is found in the inner and outer gill of the female (See Pl. LXXXVII, fig. 13), and the conformation of the edge of the gill is practically

identical with that of the male in all sterile individuals. There is no change in this matter in the gravid females of the genera *Unio*, *Pleurobema*, and *Quadrula*. The result is that the edge of the marsupial gill does not participate in the swelling of the gill. The greatest swelling in these genera occurs near the base or in the middle of the gill, while it decreases toward the edge, which always remains rather sharp, and *this sharp edge of the marsupial gill is a very important macroscopical character* in the species of these genera. A microscopical examination shows that there is no difference of the structure of the edge from that of the sterile female (Compare Pl. LXXXVII, figs. 13, 14, 16; Pl. LXXXVIII, fig. 1).

In our other *Unionidæ* it is different, and we distinguish two types of development, though in all cases the differentiation concerns only the edge of the outer, or marsupial gill.

The first type is found in the *Anodonta*-group (in those forms, which have the water-tubes divided into three tubes, as described above). It has already been said that in these forms the marsupium swells to an extreme degree, and this immense swelling also affects the edge. The two laminæ of the gill draw apart at the edge, and this strain would cause a rupture at this point, if it were not for the fact that there is here an extraordinary thickness of tissue, *which is capable of stretching*, and thus keeps the edge of the gill closed (See Pl. LXXXVIII, figs. 2*b*, 3*b*, 5, 10). There are no filaments, or chitinous rods, or ostia visible in this elastic tissue.

This transverse stretching of the edge of the gill takes place in various degrees, and is well observed only in marsupia, which are fully distended. Even in fully charged marsupia it is often absent in certain parts, chiefly so toward the anterior and posterior ends of the edge of the gill, which then remains simple, but appears as a kind of ridge or cord upon the swollen marsupium. In the middle of the gill, however, this stretching takes place regularly, and is sometimes accompanied by a slight bulging out of the edge, beyond the original margin of the gill (Pl. LXXXVIII, figs. 3*b*, 10). In other cases such bulging is hardly noticeable, and the edge of the gill does not appear rounded off, but rather truncated (Pl. LXXXVIII, figs. 2*b*, 5). The peculiarities of this structure may be easily seen with the naked eye or with an ordinary magnifying glass, and the most striking effect is that the edge of the marsupium in these forms *does not appear sharp*, as in the *Unio*-group, *but blunt, rounded off, or truncated*. The single water-tubes (or ovisacs) are not distinctly marked off externally along the edge of the marsupium.

The other type of the specialization occurring on the edge of the marsupium is found in the *Lampsilis*-group, to which belong the following genera and species of Simpson's "Synopsis," females of which I have investigated:

Truncilla triquetra Rafinesque; *T. perplexa rangiana* (Lea); *Micromya fabalis* (Lea); *Lampsilis ventricosa* (Barnes); *L. ovata* (Say); *L. cariosa* (Say); *L. multiradiata* (Lea); *L. radiata* (Gmelin); *L. luteola* (Lamarck); *L. ligamentina* (Lamarck); *L. orbiculata* (Hildreth); *L. recta* (Lamarck); *L. nasuta* (Say); *L. iris* (Lea); *L. parva* (Barnes); *L. alata* (Say); *L. gracilis* (Barnes); *Obovaria retusa* (Lamarck); *O. circulus* (Lea); *O. ellipsis* (Lea); *Plagiola securis* (Lea); *Obliquaria reflexa* Rafinesque; *Ptychobranchus phaseolus* (Hildreth).

This type resembles the one just described in so far as the two laminæ of the gill yield at the edge to the tendency of the marsupium to swell. The swelling of the gill itself is generally not carried to the same excessive degree as in the *Anodonta*-group, although it is sometimes quite considerable; in its stead, the chief expansion takes place *at the edge itself, and in this case beyond it.* The thickened tissue is not simply stretched out in a transverse direction, but it bulges out, thus protruding beyond the original edge of the gill (See Pl. LXXXVIII, fig. 14). The latter is always clearly indicated by a line at which the filaments and their chitinous rods stop; and this line may be seen with the naked eye or with a low power lens. Beyond this line the gill sometimes projects to a considerable distance, and this projection, into which the septa are continued, acquires a peculiar appearance. It does not project and bulge out uniformly, but the septa on the inside, acting as stays, check the bulging at their lines of insertion, and thus the edge of the marsupium assumes *a beaded appearance,* each bead representing a water-tube, being separated from the adjoining bead by a kind of constriction or sulcus, representing the septum. This protruding, beaded structure of the marsupial edge is very characteristic of these forms, and is distinctly visible to the naked eye. Apparently Simpson's diagnostic character, that here the ovisacs are distinctly "marked out by a sulcus," refers to the edge of the marsupium; for upon the lateral faces of the marsupium there are no such distinct sulci, and there is hardly any difference in the appearance of these faces from what is seen in the other genera, which, according to Simpson, have no such sulci. However, when the water-tubes are very large, as for instance in *Lampsilis alata* and *gracilis,* the sulci are a little more distinct on the lateral faces.

In the genus *Ptychobranchus* (Pl. LXXXVIII, figs. 13, 14), the bulging out of the edge takes place *all along the gill,* which, in addition, is peculiarly folded, as is well known. In the rest of the genera the bulging is localized, and it is always the *posterior section of the outer gill* which shows this structure, sometimes to a greater, sometimes to a lesser extent. The fact that the marsupium is restricted in these genera, is a character emphasized by Simpson. There is some differentia-

tion in this, for instance in *Obliquaria* it is only a small part of the gill immediately behind the middle which forms the marsupium. But this is, in my opinion, rather unimportant, for in the typical forms of *Lampsilis*, *Obovaria*, and *Plagiola* very often the outmost posterior end of the outer gill is not used as marsupium. But it is without exception a rule that the marsupial part always *projects* beyond the original edge of the gill (as marked by the filaments); and this is also noticed, although in a lesser degree, in the sterile female. When the gills are not charged, of course, the protruding, outbulging tissue is much contracted; yet the mass of this tissue is so considerable, that it is even then clearly seen, and it keeps the laminæ of the gill permanently apart at the edge (See Pl. LXXXVIII, figs. 13, 15, 17, 21), so that the beaded appearance is also preserved. By this character a female of these forms may always be recognized even when sterile, and further the marsupial edge may generally be distinguished by its color. Often it appears simply opaque whitish, in distinction from the water-soaked, transparent tissue of the rest of the gill, but in other cases a peculiar dark pigment develops, chiefly on the inner side of this tissue in the epithelial layers (See Pl. LXXXVIII, figs. 15, 17, 18, 19, 20).

The part of the outer gill of the female which is not used as marsupium has the normal structure, that is to say, it corresponds essentially to the structure of the edge of the outer gill of the male. In sterile females it simply forms the anterior continuation of the marsupial part, and is not marked off, except by the lesser elevation of the edge (Pl. LXXXVII, figs. 6, 7, 10). In the gravid female, however, the marsupium swells principally at the edge, and it also increases its longitudinal (antero-posterior) dimension. Thus it is forced to push past the anterior part of the gill, forming a fold with it (See Pl. LXXXVII, fig. 5). This fold probably is analogous to the numerous folds seen in the genus *Ptychobranchus* (Pl. LXXXVII, fig. 3), at any rate it serves the same purpose. Sometimes, when also the hindmost part of the outer gill does not take part in the formation of the marsupium, a similar small fold is also seen posteriorly, but this is rather insignificant and variable. At the anterior fold, the marsupium pushes forward on the *inside* of the anterior, non-marsupial part of the gill.

C. The ova and the larvæ (glochidia).[4]

1. *Arrangement of the ova and embryos in the marsupium.*

As is well known, the *sexual orifices* are situated on each side of the abdominal sac, and open into the anterior part of the suprabranchial canal of the inner gill.

[4]Wherever I use the words "ova" or "eggs," as distinguished from "glochidia," I mean the eggs and their subsequent stages of development, before the glochidial shell is formed.

From this point the way is open for the eggs all along the base of the inner gill backward to the common cloacal chamber and forward again into the suprabranchial canal of the outer gill. From the suprabranchial canals at the bases of the gills the ova reach the water-tubes in the gills. I have repeatedly found specimens, in which this process was going on, and where both suprabranchial canals were more or less filled with ova. (Instances are *Ptychobranchus phaseolus, Strophitus edentulus, Alasmidonta undulata, Quadrula undulata.*)

After the eggs have reached the water-tubes (*ovisacs*), they are firmly packed together there, until the marsupium is filled to its utmost capacity. In no case have I observed that the ova become connected in any way with the tissue of the gills; on the contrary, they always remain free from them, but generally are connected with each other, so that the contents of each water-tube or ovisac form a more or less solid mass, which in its shape conforms to the shape of the ovisac. The connection of the eggs between themselves is merely a "sticking together," which sometimes is rather slight, but produces in other cases a rather firm mutual adhesion. It is accomplished by the outer egg-membranes, which apparently have the property of freely imbibing water, and thus of becoming gelatinous.[5] For these gelatinous masses containing the eggs we may use the term *placentæ,* introduced first by Sterki with reference to the genus *Strophitus.* (As will be seen later, I call the *placentæ* of Strophitus *placentulæ.*) These placentæ may be more or less compact (See Pl. LXXXVI, fig. 3; Pl. LXXXVII, fig. 3; Pl. LXXXVIII, fig. 14); they are well developed in *Quadrula subrotunda, kirtlandiana,* and *rubiginosa,* where they are rather cylindrical, since the water-tubes do not expand very much and remain subcylindrical in the charged marsupium. In *Ptychobranchus* the placentæ are also very solid, and there is in the outer layer a peculiar brown stain developed, when the glochidia are formed. The placentæ are subcylindrical here, but somewhat club-shaped, on account of the swollen distal end. In all these forms, it is easy to take the placentæ out of the gill whole, without injury.

In *Quadrula metanevra, undulata, coccinea,* in the species of *Pleurobema* and *Unio,* in all forms of the *Lampsilis*-type (except *Ptychobranchus*), the water-tubes are more or less stretched out transversely, so that their lumen becomes compressed, and consequently also the placentæ have a similar shape, leaf-like, lanceolate, or elliptical. Here the mutual adhesion of the eggs is not so firm, so that they come apart more easily, and it is not feasible to take the placentæ out entire. In some of these forms (*Quadrula undulata, Unio,* and the *Lampsilis*-species), the adhesion

[5]There may be a secretion furnished by the epithelium of the water-tubes. This question is reserved for further histological investigation.

is noticed only in the eggs, while later on the glochidia are more or less free. In *Quadrula coccinea* and *Pleurobema*, however, the placentæ are more solid, and remain so until they are discharged (See below).

In *Strophitus*, as we have mentioned, peculiar conditions prevail. The ovisac (inner part of a water-tube) is subdivided into smaller partitions, running crosswise to the gill; and in each of these compartments, which are almost cylindrical, a small number of ova are located which again stick together rather firmly and can easily be taken out whole. These "placentæ" of Sterki, consequently, are not entirely homologous to the placentæ of the other genera, since in the latter each ovisac contains only one placenta, while in *Strophitus* there are many of them in one ovisac. The eggs of *Strophitus* form a single, irregular row in each *placentula*, as I should prefer to call them here, and there are from about two to eight or ten (generally seven) in each placentula.[6]

In the genera *Anodonta*, *Anodontoides*, *Symphynota*, and *Alasmidonta*, no placentæ appear to be present. The eggs as well as the glochidia fill the ovisacs in immense numbers, and seem to be entirely free. At any rate I never succeeded in isolating the egg-mass from an ovisac, but invariably, as soon as an ovisac is injured, the eggs or glochidia flow out freely, without sticking together, although in some instances in some of my sections of the genus *Symphynota*, a placenta-like cohesion is here and there indicated in the younger eggs.

2. *The Glochidia.*

I am not prepared to say where the *fertilization* of the eggs takes place. It must take place somewhere between their issue from the genital orifice, and their final deposition in the gills. It may take place in the suprabranchial canals, or in the gills. At any rate as soon as the marsupium is well filled cleavage begins, and the eggs develop within the gill into the young larval shell, known as *glochidium*. The development from the egg to the glochidium is rather rapid, while the glochidium may remain unchanged a long time in the marsupium before it is discharged.

We generally find in individual shells a rather uniform stage of development of the embryos, and, as a rule, when there are eggs, there are only eggs, and when there are glochidia, we find only these. Nevertheless, as already observed by Sterki (1898, p. 19) in *Cyprogenia*, there are sometimes cases, where all stages from the egg to the fully developed glochidium are found in one and the same marsupium.

[6]I have evidence in some of my slides that not all eggs in a placentula of *Strophitus* develop into glochidia, but that some become abortive. It may possibly be that the latter furnish material for the placentulæ. In other species also I have seen what looks like abortive eggs (see *Lampsilis alata*, Pl. LXXXIX, fig. 18). This matter should be investigated more closely. Sterki (1898, p. 19) already mentions it.

I have seen the identical condition in *Anodontoides* and *Symphynota*, with young eggs at the base of the gills, glochidia near the edge, and with the intermediate stages in the middle.

The *shape of the glochidium* has been studied repeatedly by different writers, but the credit of using it successfully for the systematic arrangement of the genera belongs to Sterki. The glochidium of *Anodonta* possibly is best known. It is rather large, subtriangular, with a spine at the tip of each valve (Pl. LXXXIX, fig. 13). Yet this shape cannot be regarded as typical, and it represents a specialization. As Sterki points out, it is found only in that group of genera, which I have repeatedly called the *Anodonta*-group, and it is one of the diagnostic features of this group.

I have seen this glochidium in the following forms: *Strophitus edentulus* (Say); *Anodonta grandis* Say; *A. imbecillis* Say (Pl. LXXXIX, fig. 13); *Anodontoides ferussacianus* (Lea) (Pl. LXXXIX, fig. 12); *Symphynota compressa* Lea (Pl. LXXXIX, fig. 10); *S. viridis* (Conrad); *S. costata* (Rafinesque); *S. complanata* (Barnes) (Pl. LXXXIX, fig. 11); *Alasmidonta undulata* (Say) (Pl. LXXXIX, fig. 9); *A. marginata* (Say); *A. marginata varicosa* (Lamarck); *A. heterodon* (Lea) (Pl. LXXXIX, fig. 8).

In all these the glochidia are rather uniform in size as well as in shape. Generally they are rather high and pointed, but sometimes (*Symphynota compressa* and *viridis*) they are wider and less pointed. We do not need to go into detail here, since most of them have been already figured by Lea (Observ. VI and XIII).[7] The glochidia of *Alasmidonta undulata* and *Anodontoides ferussacianus* are here figured for the first time (Pl. LXXXIX, figs. 9 and 12).

Lea, who is the only writer, who has furnished drawings of the glochidia, has observed the same type in the following additional species: *Margaritana deltoidea* (= *Alasmidonta calceola*) (See Observ. VI); *Margaritana spillmanni* (= *Strophitus spillmanni*) (See Observ. XIII). They also belong to the same group. On the other hand, Lea says of *Margaritana triangulata* (= *Alasmidonta triangulata*) (See Observ. VI) from Georgia, that he could not observe any hooks, and the same is the case in *Margaritana hildrethiana* (= *Hemilastena ambigua*, see Observ. VI), *Anodonta ferussaciana* (= *Anodontoides ferussaciana* ibid.), and in *Anodonta ovata* (= *grandis*, see Observ. X). All these species should have hooks, if Sterki's theory, that this is a fundamental character of the glochidia of this group, is correct.

[7]A number of Lea's figures are rather unsatisfactory, because they are not drawn to scale. Thus, for instance, the glochidium of *Plagiola securis* (Observ. VI, pl. 5, fig. 6) does not show its real character, being too small in comparison with those of other species (also the gaping margins are not shown). The glochidia on our Plate LXXXIX are all from photographs taken under the same enlargement, and thus show the actual comparative proportions.

And indeed I have seen the hooks in the two last-named species. Lea himself in the case of *Hemilastena* suggests that the glochidia he has seen are too young, and that the hooks might develop later. And this is apparently true, for I have observed in a number of species, that young glochidia have no hooks, while they are present in older ones. In the following cases this was most evident: specimens of *Alasmidonta marginata*, collected Sept. 2, 1907; of *Alasmidonta marginata varicosa*, collected Aug. 13, 1908; of *Symphynota viridis*, collected Sept. 6, 1909; of *Symphynota costata*, collected Aug. 31, 1906, and Sept. 21, 1907; of *Symphynota complanata*, collected Sept. 14, 1909; and of *Strophitus edentulus*, collected Aug. 24, 1909. All had no hooks, and we see that they all were collected in the months of August and September, the beginning of the breeding season. In other specimens of the identical species, collected generally a littler later in the season or in the spring, hooks (spines) were present.

Thus we have every reason to believe that Sterki's opinion that this kind of glochidium is common to, and characteristic of, the genera *Strophitus*, *Alasmidonta*, and *Anodonta*, is essentially correct, and that it should be enlarged so as to embrace all forms belonging to the "*Anodonta*-group."

A second type of glochidium presents a somewhat rectangular shape, more or less dilated ventrally (celt-shaped), with two spines or hooks, one at each of the ventral corners of the shell; further the lateral (anterior and posterior) margins of this shell are here not in contact all along their edges, as usual, but are gaping. In Pennsylvanian species, I have only observed this type in *Lampsilis alata* (Say) (See Pl. LXXXIX, fig. 18), and in addition in *L. lævissima* (Lea), from Kansas. Lea describes it (Observ. X and XIII) from the same species and from *L. purpurata* (Lamarck).

These species stand in Simpson's system in the subgenus *Proptera* of *Lampsilis*. This has induced Sterki to believe that this shape of glochidium is common to all forms belonging to *Proptera*, and to elevate it, on that account, to generic rank.

Although I agree with Sterki in making *Proptera* a genus by itself, I would not place all species listed under Simpson's subgenus into it, for we have at least one species, which has a glochidium of a different shape. This is *Lampsilis* (*Proptera*) *gracilis* (Barnes) (See Pl. LXXXIX, fig. 19). Here the glochidia are *in shape* similar to those of the third type, to be described presently, but they differ considerably from them *in size*, for they are much smaller. In fact, the glochidia of this species are by far the smallest I know among our *Unionidæ*. The natural consequence is that we are compelled to create a new genus (*Paraptera*) for it.

In the shape of the glochidia *Lampsilis alata* (and the forms allied to it)

stands rather isolated, but the gaping margins are found at least in one other species, *Plagiola securis* (Lea) (See Pl. LXXXIX, fig. 17).[8] Here the general shape is similar to the third type, but it is rather distinctly spatulate and quite large. I think that the glochidium of *Plagiola securis* is the only one which might be compared with that of *Lampsilis alata*, and it is rather significant that the only glochidium, which permits such a comparison, is found in a group, which, as we shall see later, is rather closely allied to *Proptera*.

The third type of glochidium is found in all the rest of the genera of Simpson investigated by myself. Here the shell is semicircular or semielliptical, the ventral margin evenly rounded, and no spines are present. With the exception of *Plagiola securis* the margins shut completely. There are minor differences in size and shape; as has been mentioned, those of *Paraptera gracilis* are very small (See Pl. LXXXIX, fig. 19). Of those of the genera *Quadrula*, *Pleurobema*, *Unio*, *Ptychobranchus*, and *Obovaria*, we may say, that they are generally rather small, while those of *Lampsilis* and *Truncilla* are somewhat larger.

The following is a list of the Pennsylvanian species, in which I have seen glochidia of this type: *Truncilla triquetra* Rafinesque (Pl. LXXXIX, fig. 24); *Truncilla perplexa rangiana* (Lea); *Lampsilis ventricosa* (Barnes) (Pl. LXXXIX, fig. 23); *L. ovata* (Say); *L. cariosa* (Say); *L. multiradiata* (Lea); *L. luteola* (Lamarck); *L. ligamentina* (Lamarck) (Pl. LXXXIX, fig. 16); *L. orbiculata* (Hildreth) (Pl. LXXXIX, fig. 22); *L. recta* (Lamarck) (Pl. LXXXIX, fig. 21); *L. nasuta* (Say); *L. iris* (Lea) (Pl. LXXXIX, fig. 20); *L. gracilis* (Barnes) (Pl. LXXXIX, fig. 19); *Obovaria circulus* (Lea) (Pl. LXXIXX, fig. 15); *Plagiola securis* (Lea) (Pl. LXXXIX, fig. 17); *Ptychobranchus phaseolus* (Hildreth) (Pl. LXXXIX, fig. 14); *Unio crassidens* Lamarck (Pl. LXXXIX, fig. 6); *Unio gibbosus* Barnes (Pl. LXXXIX, fig. 7); *Pleurobema clava* (Lamarck) (Pl. LXXXIX, fig. 5); *Quadrula undulata* (Barnes) (Pl. LXXXIX, fig. 3); *Q. coccinea* (Conrad) (Pl. LXXXIX, fig. 4); *Q. rubiginosa* (Lea) (Pl. LXXXIX, fig. 2); *Q. subrotunda* (Lea); *Q. kirtlandiana* (Lea) (Pl. LXXXIX, fig. 1).

Other Pennsylvanian species, the glochidia of which are known to be of this type (See Lea, Observ. VII and X), but have not been seen by myself, are: *Lampsilis radiata* (Gmelin), *L. parva* (Barnes), and *Obovaria retusa* (Lamarck).

3. *The breeding season.*

Lea (Observ., II, III, VII, X) had already paid attention to the time of breeding of the *Unionidæ*. Sterki (1898 and 1903) has pointed out that there are

[8]See footnote on page 300.

important differences between the different forms with regard to the time, when the marsupium is filled, and the present writer has devoted a special article to this topic as far as it concerns the Pennsylvanian species (Nautilus, 1909), which confirms and supplements Sterki's observations. Additional facts have been furnished by Conner (1909, p. 112).

Since the publication of my paper in 1909, I have made a large number of further observations, which generally serve to support my previous conclusions, and the microscopical investigation of the contents of the marsupia of soft parts at hand has added a number of more important facts. These new observations will be reserved for the systematic part, and will be treated under each species. Here I shall give only a condensed statement of the results obtained by Sterki and myself, and a few considerations as to their systematic value.

Among our *Najades*, we have in our latitude two types, *summer-breeders* and *winter-breeders*. Those belonging to the first class, have the marsupium filled only in summer, that is to say, in the period between the end of April and the beginning of August. Of course this indicates the extremes; for in the case of single species and single individuals the breeding season is much shorter; and the month of June, and the beginning of July is generally the time when most of these forms are gravid. The development from the egg to the glochidium takes place within *a very short time* (a few weeks), and, after the glochidia are formed, they are discharged immediately. The consequence is that individuals with glochidia are rather rarely found.

It is a remarkable fact, first pointed out by Sterki, that summer-breeders are found only in a restricted group of genera; and, as we shall see, this physiological character is *always* found in the forms belonging to this group. It is composed of the genera: *Quadrula*, *Pleurobema*, and *Unio* of Simpson, and, as may be seen from the description of their soft parts given above, these, according to their morphological characters, form a group by themselves. Likewise the genus *Margaritana*, which stands by itself in the system, seems to be a summer-breeder; at all events, Conner (1909, p. 112) found gravid females in June and August, but not in November and January, and I failed to find them in the beginning of May, the beginning of June, and on August 4. (At the latter date only one specimen was taken.) In Europe, *Margaritana* is known to breed in July and August (See Harms, 1907, p. 818).

All other genera are winter-breeders. In these the marsupia fill some time in summer, from July to September. The development of the eggs also takes place rapidly, and generally the glochidia are fully developed in September or

October. However, *they are not,* as a rule, *then discharged, but are carried through the winter in the marsupium, and are not set free till warmer weather sets in again,* in April, May, or June of the next year.

Among the winter-breeders we have in some cases the breeding season still more extended, so that in summer (June, July) the end of one season overlaps with the beginning of the next (of course, not in the same individual), and in such forms gravid females may be found all the year round.

In order to understand these conditions, we must inquire what are their essential features. Sterki used the terms *summer-* and *winter-breeders,* and he certainly was right so far as it concerns the species in our latitude.[9] But in my opinion, the most important difference of the two groups is, that in the one case the breeding season is *short,* and the glochidia are discharged immediately, while in the other case it is *long,* and the glochidia are kept in the marsupium for a long time. This would be well expressed if we call the summer-breeders *tachytictic* forms, and the winter-breeders *bradytictic* forms.[10] It seems to me, that the former condition is the primitive and original one, while the latter is apparently a special adaptation to the climatic conditions of higher latitudes. From this point of view we gain a rather satisfactory interpretation of the *raison d'être* of the two types, and also ascertain a very significant correlation between these physiological characters and certain morphological features.

If a short breeding season is the more primitive condition, we can understand perfectly well, that those *Najades,* which are tachytictic, have also a comparatively primitive and simple morphological structure in their marsupium. This is actually the case in *Margaritana* as well as in *Quadrula, Pleurobema,* and *Unio.* On the other hand, in the forms with a long breeding season we should expect morphological adaptations conforming to it. And this is actually the case. In the *Anodonta*-group we have seen, that there exists a very complex structure of the marsupium, the purpose of which apparently is, to furnish a proper water circulation for the embryos enclosed in the marsupium (See above, p. 293), and in all members of this group the embryos stay a long time in the marsupium. In the members of the *Lampsilis*-group, which also are *bradytictic,* the *Anodonta*-structure is not present. But we have become acquainted above with a peculiar bulging out of the marsupium, which apparently serves the same purpose, namely to bring the glochidia into closer contact with the water, since the membrane which covers this outbulging marsupium is very thin. But in addition, I shall describe below

[9]I know cases of exotic forms, which behave like summer-breeders, but do not breed in "summer."

[10]From *ταχὺς* quick, *βραδὺς* slow, and *τικτικός* breeding.

certain other structures (flaps and papillæ of the edge of the mantle), which most emphatically serve for the aëration of the marsupium, and thus are to be regarded as adaptations to a long breeding season.

Having thus correlated physiological function with anatomical and morphological structures, we may rest assured, that we have discovered an essential principle in the development of the *Najades*, and we may say with all confidence that a systematic arrangement, which is founded upon such structures, which we are able to understand, must be the correct one. Sterki's discovery of summer- and winter-breeders, although originally not fully understood, thus becomes the most important step in our knowledge of the system of the *Najades*.

4. *The discharge of the Glochidia.*

As may be inferred from the above, the discharging of the glochidia must take place at two different seasons: in the bradytictic forms in spring or early summer (April to June),[11] in the tachytictic forms from the end of June to August. While this fact is beyond doubt, the manner of discharge remains yet to be investigated, and for some time this proved a serious puzzle to me. But now I am satisfied that my observations are complete enough to answer the question.

Lea repeatedly observed the discharge of the glochidia and placentæ, but he only mentions that they come out of the shell at the posterior end (in *Lampsilis radiata, L. parva, Strophitus edentulus* (Observ. X), and *Unio complanatus* (Observ. II), and he further quotes (Observ. III) a similar fact as observed by Kirtland in *Quadrula cylindrica*. As we shall see, these observations are probably correct, and represent the normal conditions.

On the other hand, Lea (Observ. II, p. 52) reports that in a gravid female of *Anodonta fluviatilis* (= *cataracta*) he made the young come "from the orifice at the inferior part" (= edge) of the marsupium, by the pressure of his fingers upon the sides of the marsupium. I consider this not normal, but an artificial effect, in fact, there are no such "orifices."

Other authors do not treat of the discharge of the glochidia, except that Simpson (1900, p. 616) incidentally expresses the opinion, that in *Strophitus* the placentulæ are discharged through the walls of the gills, which, as I believe, is entirely wrong.

[11]Sometimes it is postponed to the beginning of July, chiefly so in Lake Erie. Lea has repeatedly and in various species observed discharges during winter. These always took place, however, in the case of specimens kept in captivity under artificial conditions, which probably induced an abnormally early discharge. Since the glochidia of bradytictic forms are fully developed in the beginning of the winter, artificial conditions (temperature for instance) might start the discharge at any time during the winter.

Considering the anatomical structure of the gills, and the fact, that the embryos are contained in the water-tubes, we should expect, *a priori*, that the discharge would take place by the natural channels. This would be by the way of the suprabranchial canals into the cloacal chamber, and thence outward through the anal opening of the mantle. And indeed, I have collected evidence for this natural discharge in a number of cases, which furnish positive proof of it. They are the following: In cutting up specimens of *Quadrula subrotunda*, on June 22 and 24, 1909, I repeatedly observed placentæ coming out of the anal opening. Of course, this might be due to rough handling, but I have never seen them coming out at any other place, unless I forced them out by so strong a pressure, that the walls of the gills burst open. On June 24, 1909, I collected a good number of specimens of *Quadrula subrotunda* and *coccinea*, which I took home alive, and kept over night in a bucket with water. The next morning I saw quite a number of placentæ floating in the water and was able to distinguish easily those belonging to the first species, which are subcylindrical and pink, from those belonging to the second, which are flattened (leaf-shaped or lanceolate) and white. On June 23, 1910, I took home a number of gravid *Quadrula coccinea*, and watched the discharge of the placentæ. They distinctly came out of the anal opening. On June 24, I opened one of these specimens, and saw the placentæ slowly moving out from the water-tubes through the suprabranchial canal to the anal siphon. While I was holding this specimen in my hand (with the shell opened and the left half of the mantle thrown back), four placentæ moved out. The coming out was not by a jerk or a squirt, but was slow and gradual, as if carried by a steady current of water. A second specimen, opened shortly after this, exhibited the same phenomenon. On July 25, 1910, two specimens of *Pleurobema æsopus* were found in the act of discharging placentæ. One was seen in the water, with a number of pink placentæ lying behind the posterior end of the shell, which were greedily devoured by a number of minnows. The other was taken home, and the discharge was observed at leisure in a basin of water. The pink placentæ came slowly out of the anal opening, often in pairs, and sometimes, when the shell was squirting water out of the anal opening, a number of placentæ were thrown out. Among my alcoholic material, there are several individuals, which were preserved in the act of discharging glochidia in the natural way. The best specimen is an *Anodontoides ferussacianus*, collected May 14, 1908, which has the posterior half of either marsupium empty (discharged), while the anterior half is yet full. Here I observe, that the suprabranchial canals of the marsupial gills are crowded with loose glochidia back to the cloacal cavity, and a mass of glochidia is located

in the anal opening. The dark brown color of the glochidia contrasts strongly with the whitish, semitransparent tissue at the base of the gills, and thus the suprabranchial canals are easily traced by this color. The same phenomenon was seen in a specimen of *Quadrula undulata*, collected July 8, 1909, where also numerous loose glochidia, but of whitish color, were found in the suprabranchial canals of all four gills. On May 13, 1910, a specimen of *Symphynota costata* was found, also in the act of discharging loose, brown glochidia through the suprabranchial canals. The glochidia were not plentiful in the canals. This specimen was not preserved. An additional case, corresponding closely to the instances just mentioned, was observed on July 12, 1910, in *Anodonta imbecillis*. Finally, I have observed in alcoholic material of five specimens of *Strophitus edentulus* collected April 22 and 24, 1908, a similar condition. But here there were whole placentulæ as well as free glochidia in the outer suprabranchial canals, and in no case were they very numerous.

Entirely different from these are the following observations:

In a gravid female of *Ptychobranchus phaseolus* (collected August 31, 1906; probably unusually delayed in the discharge), there were on the margin of the right marsupium about half a dozen placentæ protruding through and beyond the edge, that is to say, in the act of escaping from the marsupium *through openings in the outbulging edge of the gill*. This peculiar fact suggested to me the idea, that the discharge of the glochidia might take place here not by the natural channels and the anal opening, but by breaking through the edge of the marsupium into the branchial cavity, and thence through the branchial opening into the surrounding water. I consequently made a careful search among my material for additional specimens caught in the same act, and I found indeed such evidence for this "unnatural" discharge. What I was able to ascertain is that there are actually, at the time of the discharge, *holes breaking through the edge of the marsupium*, which thus furnish an outlet for the glochidia. These holes may be seen macroscopically, and are also shown quite satisfactorily in some of my slides. The best slides I have are made from *Lampsilis luteola* and *multiradiata* (See Pl. LXXXVIII, figs. 18 and 20). But I also possess such from *Lampsilis nasuta* and *Obovaria circulus*, which show this feature, although less distinctly. I remember further, to have noticed macroscopically these holes in *Lampsilis alata*, but I did not succeed in obtaining a satisfactory slide, and I have a slide of *Lampsilis gracilis* (See Pl. LXXXVIII, fig. 16), which shows, as I believe, the closing up of these holes after the discharge of the contents of the ovisacs.

In 1910 I found similar instances. A specimen of *Ptychobranchus phaseolus*,

collected June 27, had most of the placentæ discharged, but of the remaining few, some were protruding from the edge of the gill, exactly as described above. Females, discharging glochidia, and with openings in the edge of the marsupium, were seen in the following additional cases: *Lampsilis luteola*, May 6 and July 7 (on the latter date in several individuals); *Lampsilis ventricosa*, May 21 and June 23; *Lampsilis multiradiata*, June 23.

To all appearance, these holes are present only during the actual discharge of the placentæ or the glochidia, and immediately after it, and close up again very soon, so that it is difficult in sectioning, to strike just the right point of the edge of the gill, where they are best visible, and this may account for my failure to obtain a greater number of good slides. It also should be remembered, that gravid females in the act of discharging, are naturally scarce among material, which was not collected with this question in view, and it is indeed astonishing, that I found so many instances supporting the assumption, that in the *Lampsilis*-group, that is to say, in those forms, in which the edge of the marsupium bulges out beyond the original marginal line of the gill, the glochidia are discharged, not by way of the natural outlets, but by breaking through the marginal wall of the gill. If this is so, a very important correlation is suggested: the anatomical peculiarities of the edge of the marsupium in these forms appear as a direct adaptation to the way of discharging the glochidia: *the edge of the marsupium is built for this purpose.*

Nevertheless this phenomenon should be further studied. I have given here my observations, and I think they are correct and conclusive, for I cannot imagine that conditions as represented in the figures 18 and 20 on Plate LXXXVIII are wholly artificial and abnormal.

From the above instances we see, as well as from some of the older observations of Lea, that in some cases the whole placentæ are discharged, in others free glochidia. This is connected with the greater or lesser solidity of the placentæ (See above, p. 298), but its systematic value is not very great; at any rate, each one of the greater groups contains examples of either method of discharge.

D. Hermaphroditism.

Lea and others have demonstrated that most of our *Unionidæ* are *gonochorists*, and the existence of *hermaphrodites* remained doubtful, till Sterki found them. In a number of cases, hermaphroditism is occasional and exceptional, according to Sterki (1898, p. 30), and he names the following instances: *Quadrula rubiginosa, Q. pryamidata, Lampsilis parva.* But in another case, that of *Anodonta imbecillis* (Nautilus, 12, 1898, p. 87), he found that *hermaphroditism is the normal condition.*

Sterki decided this question by investigating the sexual glands. Since I have found that the sex of any individual may be determined by an examination of the gills, it should be possible, to recognize hermaphroditism by the structure of the latter, for in the case of hermaphroditism *no individual should be found exhibiting the male structure of the gills.*

This is indeed true, and I am not only able to confirm Sterki's observation with reference to *Anodonta imbecillis*, but in addition I think I have discovered among the Pennsylvanian species in *Symphynota compressa* and *S. viridis*, two other cases in which hermaphroditism is at least the normal condition. The particulars are as follows:

Of *Anodonta imbecillis*, until toward the end of the summer of 1909, I found only 6 specimens (in May and beginning of June), every one gravid. On September 14, 1909, I collected a large number (about thirty) of this species in the outlet of Lake Leboeuf, which again were all gravid with one exception, and the latter proved, upon anatomical examination, to be also an individual with the female structure of the gills. At that time, I was aware of the existence of this question, and was looking out for males, but was unable to find any. In 1910 I collected only a single individual, but again a gravid specimen.

In the case of *Symphynota compressa* my observations are not so positive, and only during 1909 and 1910 did I pay attention to this species with this point in view. I repeatedly collected specimens, which were not gravid, in May, June, July, and the beginning of August; but these might have been sterile females as well as males. I also collected four specimens, not gravid, on October 10, 1907 (together with gravid specimens). Of these I preserved two, believing them to be males; but upon investigation they proved to possess the female type of gills. During the month of September of 1908 I collected about twenty-five specimens, and among them there was not a single one which was not gravid. On August 18, 1909, I found about twenty specimens at one locality, and on September 27, 1909, about fifteen at another place. On these occasions I was hunting for males, but was unable to find any. On the latter date I found four very young specimens, which were not gravid. Three of these were preserved, but they also had the female gill-structure. In 1910 the result was the same. Of three specimens found every one had the female structure, or was gravid. However, from Professor Charles Brookover in Akron, Ohio, I received a specimen of *S. compressa* coming from Lake Erie, at Cedar Point, Ohio, which had the male anatomy of the gills. This is indeed very remarkable in view of the fact, that among all the specimens collected in Pennsylvania and preserved in alcohol or examined on the spot, there was not a single male, and that I was altogether unable to find a male in our state.

Of the hermaphroditic nature of *Symphynota viridis* I feel more confident. I received thirty-four specimens of this species, collected by Dr. Atkinson on July 11, 1908, and preserved the soft parts of fifteen of them. None was gravid, but they all had the female gills. In August, 1908, April, August, and September, 1909, I found this species repeatedly, altogether from fifty to sixty individuals, but all proved to be gravid, unless they were very young, and even in a number of the latter (in the second and third year of age) the female gill-structure was recognizable. In August, 1910, I collected altogether over one hundred specimens, and examined them in the field one by one, and every one had the female gill-structure. Thus in this case also I hunted in vain for males.

It would be a very strange coincidence, that I should fail to find males only in these two closely allied species, if they exist. In all other species of *Unionidæ* I never had any trouble in discovering males, provided there were more at hand than a few. In fact, it seems that the males generally slightly outnumber the females. Nevertheless I could not find them in the above cases, and even those sterile specimens, which I took home as males, turned out to have the female structure.

I therefore think that the conclusion is justified, that in these two species of *Symphynota* no males exist; and *that they are, as a rule, hermaphrodites;* although occasionally males may turn up, as is shown by the specimen from Cedar Point.

I should also add that the Carnegie Museum possesses from a branch of the Rio Grande at Mercedes, Hidalgo County, Texas, an *Anodonta*, belonging to the *imbecillis*-group, which probably is *A. henryana* Lea. There are seven specimens, and all were collected by Dr. Atkinson on May 15, 1907, and every one of them is gravid. Of course, the number is too small to express a final opinion, yet, according to my experience with other species, even among seven individuals we should expect to find both sexes. Thus in this case also it is suggested, that we have to deal with a hermaphrodite, which is also probable on account of the affinity of this species with *Anodonta imbecillis*.

I may possibly be able to give the results of further investigations of this question in the future.

E. Sex recognition in the young.

Sterki (1898, p. 29) has pointed out, that in young individuals, from two to four years old, the sexual glands are not developed, and that in those of the *Lampsilis*-type the sexual differences of the shells and the gills are not noticeable; there-

after, the marsupium begins to form, and with increasing age the number of ovisacs increases.

Since I have shown, that there are in the females of all species permanent differentiations of the marsupial gills, the question arises, whether these differences are observable at an early age, and I am able to report the following cases:

The smallest specimen of any species I ever investigated, in which the sex was recognizable, was a specimen of *Strophitus edentulus*, 17 mm. long. Here (See Pl. LXXXVI, fig. 10), in a cross-section, the septa of the outer gills were decidedly more crowded and more solid than those of the inner gills. However, the peculiar folding of the epithelium of the water-tubes (as shown in older specimens, see Pl. LXXXVI, fig. 7*b*) was not yet developed. This specimen upon the outer surface of the shell exhibited *one* growth-rest; assuming that this was formed in the first winter, this specimen would have been in its *second year*.[12]

Additional evidence, that in some species already in the *second* year the female structure of the gills begins to develop, is furnished by the following cases.

Anodonta grandis gigantea Lea. Here I found a young individual, 46 mm. long, but with only one growth-line, distinctly possessing the female structure (Pl. LXXXVI, fig. 14).

Symphynota compressa Lea. A specimen, 44 mm. long, with only one growth-rest had the female structure fully developed.

Symphynota viridis (Conrad). A number of young ones, of various sizes (18 to 31 mm. long), showed distinct traces of the female structure, and one of them (31 mm.) was even gravid (Pl. LXXXVI, fig. 11).

Besides these cases, I did not find the female type of gills in the second year in any other species, although I examined specimens of *Quadrula undulata hippopœa*, *Unio complanatus*, *Lampsilis ligamentina*, *L. multiradiata*, *L. ventricosa*, and *L. ovata*.

That specimens in the *third* year have the female structure, is shown in a specimen of *Symphynota complanata*, 35 mm. long, with two growth-lines. Here the difference of the septa of the outer gill became very striking, when compared with a male, 54 mm. long, with three growth-lines.

[12]I am aware of the fact that the value of growth-rests for the determination of age has been disputed. It is, however, beyond doubt that during each winter a growth-line is formed. It is also established, that growth-lines may form at any other time, whenever unfavorable conditions prevail. But the latter are undoubtedly abnormal and irregular. In young specimens, we may safely assume, that the first few growth-rests, chiefly when they are regular, correspond to the stoppage of growth in winter. In older ones, it is more difficult to recognize the annual growth-lines, and to distinguish them from the accidental lines. Yet in well developed specimens they may be told apart. It may incidentally be mentioned here, that in shells from Lake Erie the growth-lines are often extremely regular, simply because in the lake accidental disturbance of the summer growth is very rare, and thus only annual lines are developed.

In *Quadrula undulata hippopæa*, I found a specimen distinctly of the female type, which was 36 mm. long, and had two growth-lines; here again the female structure became very evident, after á comparison was made with a male specimen, 34 mm. long, also possessing two growth-lines.

I have an individual of *Lampsilis nasuta*, 38 mm. long, with two growth-lines, which is gravid.

That absolute size is no proper criterion in this question, is shown, for instance, in the case of *Lampsilis iris*, of which I have a specimen 33 mm. long (smaller than in the instance just mentioned) which is gravid, but has at least three distinct growth-lines, and consequently would be at least in its *fourth* year.

All other females observed, sterile or gravid, had at least three growth-rests, and should be considered as being in their *fourth year* of age, or older.

Thus it becomes apparent, that the female structure, at least in some species, develops as early as the second year, and that one at least (*Symphynota viridis*) may already become sexually mature at this time. In others, the female structure is distinctly seen in the third year, and some of them (*Lampsilis nasuta*) may bring forth progeny. Later, from the fourth year onward, the time of maturity is reached in most of the species.

F. Differentiating structures of the edge of the mantle.

Simpson in the diagnosis of a number of genera states that the edge of the mantle is "double." According to my observations, it is double along its whole extent in *all* forms. While the outer edge is closely adjacent to the margin of the hard shell, and is always simple, the inner edge, which is generally parallel and close to the outer edge, is more or less expansile, and is able to fill and close the gap between the two halves of the shell, when the adductor muscles relax, that is to say, when the shell "opens." And further, this *inner edge* of the mantle is not uniform in its structure all along its margin, but shows certain differentiating structures, some of which are systematically valuable.

1. *The anal and branchial openings* ("*siphons*").

The part of the edge of the mantle at and near the posterior end of the shell is modified so as to form what is known as the *anal* and *branchial openings*, the former lying more dorsally, and immediately above the latter. They are formed by the mutual approach of the edges of the inner mantle at certain points, and sometimes by their coalescence. The two openings are separated from one another by the diaphragm, discussed above (See p. 288), composed of the posterior ends of

the gills, which serve to draw the mantle together, although, in our species, the two sides of the latter never unite at this point (Compare fig. 4, on p. 289). The part above this point is the *anal opening*, which forms the outlet for the supra-branchial canals and the cloacal cavity (with the anus). Its upper (dorsal) boundary will be discussed below (see supra-anal opening).

Below the diaphragm is the *branchial opening*, which leads into the branchial chamber, into which the gills hang down. Its lower or anterior boundary is marked by slightly projecting lobes of the inner edge of the mantle (often indicated only by a curve reaching from posterior to the lower margin), which approach each other, and beyond which the edges of the inner mantle touch each other, but without growing together.

Anal and branchial openings generally possess on the inner edge peculiar crenulations, teeth, or papillæ, which were already studied by Lea, who took special pains to describe them accurately, believing that they might be of systematic value. He lays great stress upon the presence or absence of papillæ on the inner edge of the *anal siphon*. But according to my observations, this is not an important feature. There may be papillæ, which may be larger or smaller (always smaller than those of the branchial opening), and they pass gradually into fine teeth, scallops, or crenulations; or the edge may be practically smooth. Sometimes the teeth, or crenulations, appear different according to the state of preservation.

In most cases crenulations (wrinkles or small folds), fine teeth, or very fine papillæ are present. A smooth or almost smooth edge is found principally in the following forms: *Quadrula metanevra, Q. cylindrica, Q. tuberculata* (Rafinesque), *Anodonta grandis*, and *A. imbecillis*. In *Anodonta cataracta* I found crenulations of very variable character. On the other hand more distinct papillæ appear in *Pleurobema clava, Unio crassidens, U. gibbosus, U. complanatus, U. productus*, and *Anodontoides ferussacianus*.

The *branchial opening* always has papillæ, and they offer, although slightly varying in their development, no remarkable differentiations. They may be simpler or more complex (arborescent), and may be larger or smaller.

2. *The supra-anal opening.*

In most of our species, the upper part of the anal opening is separated from the anal by a complete union of the inner edges of the mantle, and is called the *supra-anal opening* (See fig. 4, on p. 289). This opening communicates under the united edges of the mantle with the anal opening, and its purpose is rather obscure. I am inclined to believe, that the connection of the edges of the two halves of the

mantle is the essential feature of this structure, which serves to close and define the anal siphon dorsally, while the upper opening (supra-anal), which remains unclosed, is only incidental to this, so to speak a by-product.[13]

There are a few forms, in which *no supra-anal opening* is present, that is to say, where the edges of the mantle do not at all coalesce. In our state, we have only two such forms, *Margaritana margaritifera* (See fig. 6, p. 289) and *Quadrula* (*Rotundaria*) *tuberculata*, and in each of them, we have a large, single, undivided anal opening. This feature was known previously, and in my opinion is rather significant, as showing the preservation of a primitive condition.

In all other forms, there is a connection of the margins of the mantle separating a supra-anal from the anal opening. Yet in a number of species this connection is very short, and sometimes deciduous; or it may be torn easily, or may be occasionally altogether absent. I have observed specimens with this connection missing in the following species: *Quadrula subrotunda, Q. rubiginosa, Q. coccinea, Q. obliqua, Q. undulata, Pleurobema œsopus, Unio crassidens*, and *U. gibbosus*. But on the whole, such specimens are rare and in all of these species I have found other individuals with this connection present. In some cases it seemed that this connection was naturally lacking, while in others it had been apparently torn apart by rough handling, which may happen easily, since in all these cases the connection is very short.

In other instances the connection is a little longer, but it is generally situated so that the supra-anal is a good deal longer than the connection, and than the anal opening. This condition of a rather short connection is found in all species not mentioned here as possessing a different conformation.

In certain forms the connection of the mantle becomes somewhat longer, so that it is about as long as the anal opening, and also about as long as the supra-anal. I have observed this in *Alasmidonta undulata, Symphynota complanata,* and *Anodontoides ferussacianus*.

In still other forms the connection becomes rather long, restricting the supra-anal a good deal, so that the latter is distinctly shorter than the connection, and hardly longer than the anal opening. These species are *Anodonta grandis* (fig. 4, p. 289), *Anodonta cataracta,* and *Anodonta imbecillis*.

Finally, in one case, that of *Lampsilis parva,* I found the supra-anal opening entirely closed. Of this I have only three specimens, and in one I think I have seen a very small supra-anal opening, while in the other two the inner edges of the

[13]In rare and individual cases, there is a double connection. Lea mentions a few such instances, and I have observed the same thing in *Obovaria retusa*. I consider this an abnormality.

mantle were entirely connected as far as the posterior dorsal end. Of course the outer edges of the mantle remain separated, and if only superficially investigated, the appearance of a slit-like supra-anal, identical to that of other forms, is imitated.

3. *The edge of the mantle in front of the branchial opening.*

Anterior to the branchial opening the margin of the mantle is originally without any special differentiation. The two edges are about parallel and close together to the anterior end of the animal, and do not possess any appendages in the shape of papillæ and the like. At most the inner edge is slightly crenulated, scalloped, or wrinkled, and the latter appearance often depends on the state of preservation (it becomes wrinkled by strong contraction in alcohol). The commonest condition is when the papillæ of the branchial opening suddenly become small, assume the shape of crenulations, which soon disappear, and thenceforward the inner edge appears more or less smooth. The margin of the mantle (the part under both edges), which is thickened at the branchial opening, thins out gradually, and the thickening is hardly any longer noticeable at a short distance in front of the branchial opening.

This condition is seen in all species investigated belonging to the following genera of Simpson: *Quadrula, Pleurobema, Unio, Tritogonia, Alasmidonta, Strophitus, Symphynota, Anodontoides, Anodonta,* and *Ptychobranchus.*

In *Margaritana* Lea (Observ. VII, Pl. 29, fig. 104) has figured strong, papillæ-like crenulations on the edge of the mantle for a considerable distance in front of the anal opening. He does not give a detailed description of this structure in the text. In the specimens in my possession I find that the inner edge of the mantle in this region is strongly wrinkled and crenulated, the crenulations passing posteriorly into strong papillæ, such as are usually found at the branchial opening. I do not regard this as a special differentiation of structure, but it rather appears to me to be a forward continuation of the papillæ of the branchial opening; so that we should in this case regard the branchial opening as less distinctly defined anteriorly. In fact I cannot discern any sharp demarcation of the latter, such as is seen in other species. The branchial opening in *Margaritana* is ill defined, and passes gradually into the anterior margin of the mantle, a condition which again emphasizes the primitive character of this genus.

There remain a number of genera, which are characterized by the peculiar structure of the marsupium, and in which it is restricted to the posterior part of the outer gills, and projects beyond the margin of the latter. These are the genera *Obliquaria, Plagiola, Obovaria, Lampsilis, Micromya,* and *Truncilla.* Among these we meet with interesting special structures on the edge of the mantle.

As has been said, *Ptychobranchus,* which is also associated with these genera, has the normal structure. The same holds true of *Obliquaria, Plagiola, Obovaria,* and certain species of Simpson's *Lampsilis,* namely: *L. ligamentina, alata,* and *gracilis.* But the beginning of a differentiation is here indicated. In all these the thickening of the margin of the mantle is more distinct, and extends farther forwards, sometimes as far as the middle of the ventral margin, where it disappears rather suddenly. Along this thickening we observe the inner edge of the mantle as a distinct keel, which is more or less crenulated or toothed. These teeth, which are the continuation of the papillæ of the branchial opening, are also sometimes found for a short distance in normal cases, as described above; in the present genera, however, they extend farther forward, generally as far as the thickening of the margin of the mantle, and disappear beyond, or give way to mere crenulations. *But in no case do these teeth assume the shape of papillæ,* or appear as the main feature of this structure. They are rather elements accessory to the edge of the mantle itself, which is a narrow keel or lamella, projecting from the thickened margin of the mantle. This lamellar, projecting character is most evident in *Lampsilis alata* and *gracilis.*

This structure of the edge of the mantle is present in both male and female, but it is generally more distinct in the female, chiefly so far as it refers to the thickening of the margin of the mantle and the size of the crenulations or teeth.

While we may say that in these forms the structure of the margin of the mantle is practically normal, except that its thickening, and the crenulations of the inner edge are more emphasized; we find in the remaining species of *Lampsilis,* and in *Micromya* and *Truncilla,* other and more strongly pronounced differentiations, and there are two types observable within the genus *Lampsilis* (including *Micromya*), while in *Truncilla* peculiar conditions prevail.

The *first type* is found in the following species: *Lampsilis parva, iris, nasuta, recta,* and *Micromya fabalis.* In these the thickening of the margin of the mantle is rather pronounced, and along it runs the inner lamelliform edge, which, however, is not simply crenulated or toothed, but possesses *distinct, well developed, conical, more or less regular papillæ,* which are rather sharply distinguished from the irregular, crowded, or massed papillæ of the branchial opening. These papillæ run forward in various extent, and disappear rather suddenly; generally with the disappearance of the thickening of the margin, and give way to the normal crenulations or the normal smoothness of the anterior edge. In the different species, the papillæ show the following peculiarities:

Lampsilis parva. In this species, Lea already had described and figured (Observ. VII, Pl. 29, fig. 102), what he called a "caruncle" on the edge of the mantle, just in front of the branchial opening. This is according to him a black, spongy mass, which, being quite expansible and retractile, may assume various shapes. In the three gravid specimens before me, I see a group of black, projecting papillæ standing upon the marginal thickening of the mantle, which extends about as far as the middle of the ventral margin of the mantle. This group of papillæ is rather short, and resembles indeed a "caruncle," yet does not differ in any essential respect from the structures, which will be described in the other species belonging here. It is composed of from four to six larger, and some smaller papillæ, and in front of it the inner edge is smooth.

Micromya fabalis. Lea (Observ. X) calls the edge of the mantle below the branchical opening "fringed," and Simpson (1900, p. 525) says in the generic diagnosis of *Micromya*, that it is "fringed," and in the female is "developed into a flap with a distinct, toothed ridge inside." In the only (sterile) female of *Micromya fabalis* I have seen, the structure of the edge of the mantle is similar to that of *Lampsilis parva*, only the group of papillæ extends farther forward, but not quite as far as the thickening of the margin of the mantle. The number of papillæ is greater. There are from eight to ten larger ones, and a few smaller ones, and they are further apart from each other than in *L. parva.* In the male the same structure is present, but the thickening is very slightly developed, and the papillæ are decidedly smaller, and occupy a shorter space on the edge.

Lampsilis iris. The mantle of this species (as *novi-eboraci*) has also been described by Lea (Observ. X) as "fringed," and he says that there are large, distant papillæ. This is quite correct. I observe in my specimens, that in the female there are from four to ten (according to age) very large, conical papillæ upon the inner edge of the mantle in front of the branchial opening. There are a few smaller papillæ between the larger ones, and the latter are rather remote from each other, and are placed at irregular intervals. This row of papillæ extends forwards for a considerable distance, but not quite as far as the middle of the ventral margin. It stops very suddenly, and beyond this point the inner edge of the mantle is only finely crenulated or smooth. In the male, the papillæ are much smaller.

Lampsilis nasuta. The female agrees with that of *L. iris* in the presence of papillæ, but the latter are very small, fine, and crowded, forming a rather regular row, running forward almost to the middle of the ventral margin, where they disappear rather gradually, and pass into the smooth anterior part of the inner edge of the mantle. In this species the inner edge in front of the branchial opening is

more lamellar, and the papillæ form merely a fringe on this narrow lamella. In the male of this species, the papillæ are extremely small.

Lampsilis recta. The female is like that of *L. nasuta*, but the papillæ are much larger (sometimes with two tips), rather regular, and form a crowded, very distinct row, which stops quite suddenly at about the middle of the ventral margin. The largest papillæ stand just at the point where they stop, but the difference in size is not very great, and the increase in size is slight in the postero-anterior direction. The strong development of the papillæ makes the inner edge of the mantle, on which they stand, appear as distinctly projecting beyond the irregularly crenulated or smooth anterior part. In the male, the margin of the mantle is less thickened, and the papillæ are much smaller, yet they are present.

The *second type* of development of the inner edge of the mantle, found in the genus *Lampsilis*, is observed in the following species: *L. luteola, radiata, orbiculata, ventricosa, ovata, multiradiata*, and *cariosa*. Here the specialization is shown not by a development of papillæ, but the inner edge itself is greatly enlarged. It forms a *rather broad, lamellar keel*, which stands upon the thickened margin of the mantle, possesses great powers of expansion and retraction, and occupies a considerable distance from the branchial opening forwards, as far as to about the middle of the ventral margin. Here the lamella suddenly stops, but is prolonged anteriorly into a *free, longer or shorter, ribbon-like flap*, which also may be expanded to a considerable length and again retracted.

This peculiar "flap" has been noticeed by Lea in several species (*radiata, luteola, ventricosa, ovata, multiradiata*). He also has observed that there is, in some forms on the posterior end of the lamellar expansion, right in front of the branchial opening, a very curious "eye spot" (dark, round spot, upon a light background).

Simpson mentions this character for his section *Lampsilis* of the genus *Lampsilis*, and says also that in the section *Eurynia* it is "sometimes" present. All of the species of the first section known to me possess it, but not all of the second one. Apparently Simpson did not attribute much value to this feature, and he says that it is found only in the female, and during the breeding season. According to my experience, however, it is a regular character of all species, where it is observed; and is found not only in the female, but also in the male, although in the latter only in a rudimentary condition. I have been able to make it out in all males investigated. I consider it a very important systematic character, which is connected with the aëration of the embryos in the marsupium, and consequently developed at its best in the female during the breeding season, but it is permanently present. Probably also in the other species of *Lampsilis* described above the corresponding papillæ have the same physiological function.

Lea has figured this "flap" of *Lampsilis radiata* (Observ. II, Pl. 15, figs. 48 and 49) and of *L. ventricosa* (Observ. VII, Pl. 30, fig. 107), and he calls special attention in *L. radiata* to its different shape in different individuals. Indeed in his two figures (figs. 48 and 49), there is a great difference in so far that in fig. 48 the anterior prolongation of the flap is not seen. But disregarding the possibility that this figure may be inaccurate,[14] the condition shown in fig. 48 may be either abnormal, or the anterior end of the flap may be injured, or it may not be fully expanded. (I think the latter is very likely the case.) Fig. 49 is rather correct, and also the figure of the flap of *L. ventricosa*.

I have repeatedly observed this flap in life, and have seen it in function. I made the best observations in the case of *L. ventricosa* and *multiradiata*. When the animal is undisturbed, and the posterior end of the shell is gaping, we notice, in the gravid female, that the marsupia, which are easily recognized, are pushed outward, so that they project even a little beyond the shell (already observed by Lea). They show below and in front of the branchial opening (See fig. 7). The lamellar expansions of the inner edge of the mantle occupy exactly the place, where the marsupia are visible, and are expanded on both sides of the latter, projecting beyond the margin of the shell and beyond the marsupia, forming a lateral wall on each side of the latter. In addition, the free flaps are fully expanded, appearing as prolongations of the lamellar portions, floating free in the water. This whole apparatus performs rhythmical, wave-like contractions, beginning at the posterior end, and ending at the free tips of the flaps. The contractions follow each other in quick succession (two to three in a second), and must produce a very lively current of water over the exposed edges of the marsupia. The position of the shell being generally much tilted, the animal almost "standing upon its head," and the shell being directed with its anterior end against the current, the flaps float horizontally in and with the current. I once (Sept. 15, 1909) had a chance to depict the flaps in action, standing knee-deep in the water of the Allegheny

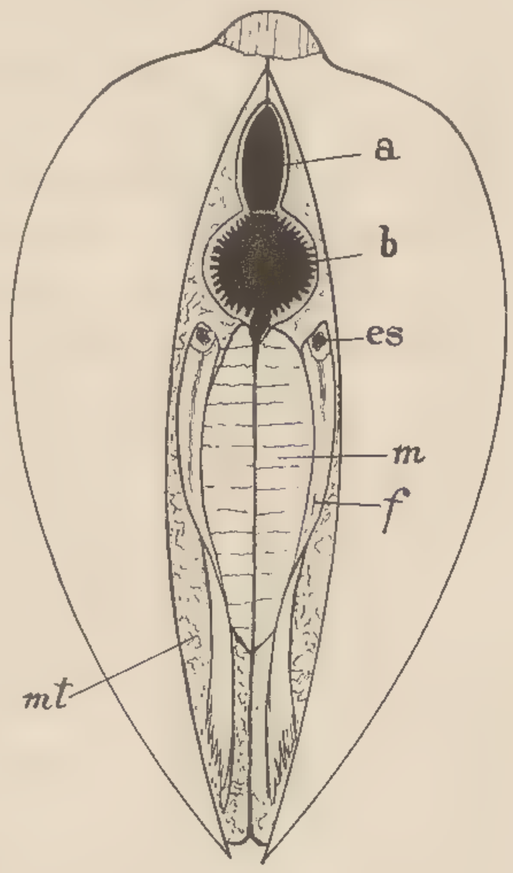

FIG. 7. *Lampsilis ventricosa* (Barnes). Shell of gravid female, seen from above and behind, showing: *a*, anal opening; *b*, branchial opening; *m*, marsupia; *mt*, mantle; and *f*, mantle flap in front of branchial opening.

[14]This is suggested by the generally poor character of the figures on this plate, which are extremely superficial and unsatisfactory.

River, at Warren, Pa. The figure here given (fig. 7) is a reproduction of this sketch. It represents a shell as seen from above, with its hind portion turned up. Allowance must be made for the difficult conditions, under which this sketch, which is rather diagrammatic, was made.

The general shape of the lamella and flap in *L. ventricosa,* is ribbon-like, much longer than wide, and the free anterior projection is rather long. It arises rather suddenly at the posterior end near to and immediately in front of the branchial opening, forming there an angle, at which the eye spot is situated. The edge of the ribbon (inner edge of mantle) is, when expanded, rather smooth, but there are, chiefly toward and at the free anterior lobe, a few irregular teeth, which give to this lobe a lacerated appearance. These teeth are quite variable. When contracted, the edge is wrinkled and crenulated, and the free lobe is much shorter, triangularly pointed or rounded off. Immediately in front of the lobe, the inner edge has a few small teeth, or it is scalloped, and becomes smooth anteriorly.

FIG. 8. *Lampsilis ventricosa* (Barnes), female. Right Mantle Flap, seen from inside.

This peculiar lamella or flap is also distinguished by its *color*. In *L. ventricosa* it is gray on the outside; on the inside it is a beautiful pale orange, with a blackish longitudinal line (See fig. 8). The thickened margin of the mantle between the inner and outer edge is also pale orange, or light brown, with black mottlings. Together with the eye spot, mentioned above, and with the whitish marsupium with its black markings on the edge, being visible between the flaps, the whole aspect of these parts in the living shell in this condition becomes rather attractive.

In the male the lamella and flap are similar, but smaller in all dimensions, the colors are less sharply defined, and the free lobe is very small, yet distinctly present.

Practically the same apparatus is seen in *L. ovata, multiradiata,* and *cariosa,* only in the two latter species the teeth of the edge are more numerous, and the black line is often missing in *L. ovata* and *cariosa.* Altogether there is much variation in the intensity of the color, the light parts shading from deep brown to light orange. The eye spot is always present in the female, but indistinct in the male. In alcoholic material, of course, the colors largely fade.

In *L. orbiculata* the same flap as in *L. ventricosa* is developed quite typically; in alcoholic material a distinct black line is seen, and between this line and the edge the flap is rather dark black. The only difference is that here the teeth along the edge are more numerous and more crowded, increasing in size in the postero-anterior direction. *L. orbiculata* generally is placed with *L. ligamentina* in the

system, but I think, according to the above observation, that it has no closer relationship with this species. The latter has no trace of a flap, in fact, it hardly shows any differentiation on the edge of the mantle. *Lampsilis ligamentina* is no *Lampsilis* at all. It is true, the males of these two species are very similar; but this is not true of the females. The peculiar shape of the female shell of *L. orbiculata* is quite remarkable, and entirely unlike that of the female *L. ligamentina.*

Lampsilis luteola and *radiata* possess a similar flap, and are practically identical with each other in this respect. Here the edge of the ribbon possesses numerous, irregular teeth, increasing in size toward the anterior free lobe; and further, there are distinct teeth on the inner edge of the mantle in front of the free lobe, diminishing in size anteriorly till the edge becomes almost smooth. In the male, the anterior end of the flap is indicated by large teeth, which gradually pass into the scalloped and smooth anterior edge, and again all parts are smaller in the male, and less typically developed. On the inside of the flap and lamella there is a broad band of black color, and there is also an eye spot posteriorly, but this is hard to see in contracted alcoholic material.

There remains the genus *Truncilla* to be discussed. In *T. triquetra* we see conditions, which somewhat approach the first group of *Lampsilis,* where there are papillæ in front of the branchial opening. The swelling of the margin of the mantle is distinct, but does not extend far forward, and the inner edge along the swelling possesses a number (four to six) of conical papillæ, which are not very large, and are followed farther forward by a number of still smaller papillæ diminishing in size. In front of these the edge is smooth. But in this species we see a feature in the female, which, although not very striking, distinctly indicates the beginning of the most prominent peculiarity of *T. perplexa rangiana,* to be discussed below. The inner edge of the mantle, where it carries the papillæ, *is not quite close and parallel to the outer edge, but runs at a certain distance from the latter,* and the space between the two edges has a peculiar spongy structure. This spongy structure is also developed to a certain degree in the species of *Lampsilis,* but it is not so markedly restricted to the posterior part of the margin, just in front of the branchial opening. In the male of *T. triquetra* the two edges are almost parallel and close together, and the papillæ of the inner edge are rather small. While in the female *T. triquetra* the separation of the inner edge from the outer is barely indicated, this condition furnishes the most striking feature in *T. perplexa rangiana.* Lea already described it (Observ. X), and Simpson (1900, p. 516) mentions it in the generic diagnosis, but without having properly understood this structure. In the female of *T. perplexa rangiana,* the inner edge of the mantle is

posteriorly, in front of the branchial opening, *widely separated from the outer edge*, and approaches the latter again at about the middle of the ventral margin. In the space between the two edges, the margin of the mantle is thick, white, and spongy, and of a peculiar structure. Thus the inner edges cut off in part a *separate chamber within the shell* at the posterior lower end of the latter. Along the inner edge in this region are fine papillæ, the largest behind, diminishing anteriorly, and becoming effaced before the edges come together again. Farther in front, the inner edge is smooth. In the male of this species, this peculiarity is not found. In this sex the two edges are almost parallel, and the papillæ of the inner are extremely small. There is no doubt, that this structure also has something to do with the aëration of the glochidia during the prolonged breeding season. But its particular action should be further studied.

I have tried to find other features of the soft parts, which might offer differentiations available for the general systematic arrangement of the *Najades* of our region, but was not successful. Thus, for instance, as Lea has already pointed out, the palpi show certain differences, but these are rather slight, and of no systematic value, and it is not necessary to give a detailed description of the latter.

We are now ready, to discuss the general system of our *Najades* with reference to the characters described above.

PART II. THE SYSTEM OF THE NORTH AMERICAN NAJADES.

A. Division into Families and Subfamilies.

In the course of the preceding investigation of the soft parts we took occasion to point out that *Margaritana margaritifera* is unique among our mussels. In fact some of the anatomical characters are so unusual, that this species appears as a stranger in our fauna, differing fundamentally from all other species. The most striking features are: (1) the absence of water-tubes in the gills; (2) the peculiar conformation of the diaphragm at the posterior end of the gills. There is not a single species among those which I have investigated, which shows even an approach to the structure seen in *Margaritana*, and the first one of these is something quite unexpected in so far that it does not conform at all to the type of gill-structure, as laid down in the text-books.

In addition, the lack of a separate supra-anal opening and the incomplete demarcation of the anterior boundary of the branchial opening present additional peculiarities. Further, although I have not seen gravid females, and am unacquainted with the marsupium and the larvæ, these are known in the European

Margaritana through the studies of Harms (1907, pp. 817 and 818). The marsupium is formed by all four gills, and the glochidium is apparently of the *Quadrula*-type.[15] These characters we must regard as expressing a distinctly primitive type of development in the case of *Margaritana*.

All this is sufficient to impress upon *Margaritana* the stamp of oddity and singularity, which justifies us in saying that this form stands by itself in the system, and should not be associated with any other form. This is best expressed by creating a family for it (*Margaritanidæ*).

Yet there is possibly another species, which may go with it, *Margaritana monodonta* (Say). The soft parts of this have been described by Lea (Observ. X), and as far as the description goes, we may say that it agrees with *Margaritana margaritifera*. Lea especially emphasizes the peculiar diaphragm and the absence of a defined supra-anal opening.

Leaving the genus *Margaritana* aside and turning our attention to the rest of our *Najades*, we find that the most prominent differentiations are found in the sexual apparatus, and chiefly in the general form and the finer anatomical structure of the marsupium. This part of the anatomy has been used by Simpson for his system. But his classification only serves in part to bring out the natural affinities. Summing up what has been discussed above, we are led to distinguish three groups among our *Unionidæ* according to the structure of the gills.

1. In some the water-tubes of all or of some gills serve, in the gravid female, as ovisacs (receptacula for the ova and embryos). Their only differentiation is in the development of the septa separating the ovisacs, which more closely approach each other, are stronger, and possess a folded epithelium, adapted to the swelling of the marsupial gill in the breeding season. There are no other modifications, and the edge of the marsupial gill is not changed, and always remains sharp. It goes without saying, that this is clearly the most primitive type of the three. There are no special adaptations to an extended breeding season, and the latter is short in all these forms,—they are tachytictic. This type is found in Simpson's genera *Unio*, *Pleurobema*, *Quadrula*, and *Tritogonia*.

I have given above the essential characters of the soft parts. Of less importance are the following: marsupial gill little or only moderately swollen in the breeding season; marsupium either formed by all four gills, or only by the outer gills in their whole length; supra-anal opening only in rare instances not separated from the anal, generally well defined by the connection of the margins of the

[15]Harms (p. 820) describes "rather strong" hooks in the glochidium, but in his figure (p. 818, fig. 4) there are only mere traces of them, and they cannot be compared, by any means, with those of the *Anodonta*-glochidium.

mantle, which is rather short, and leaves a supra-anal of considerable length; branchial opening rather well defined anteriorly; no papillæ or special structures on the edge of the mantle in front of the branchial opening; inner lamina of inner gills free from the abdominal sac;[16] glochidia imbedded in rather well developed placentæ, or placentæ poorly developed; glochidia small or of medium size, semicircular or semielliptical, with rounded ventral margin, and without spines. The discharge of the glochidia is by the natural channels through the anal opening. These forms are tachytictic.

With regard to the characters of the shell little can be said, for the shape of the shell is very variable. Generally the shell in this group is rather heavy, from more or less rounded to more or less elongate. The colors of the epidermis are dull or brighter, rarely with bright markings (rays); sometimes peculiar, odd shapes of the shell are met. The sculpture of the beak is variable, concentric, or with indications of double loops, or pustulous, or even with traces of zig-zag sculpture toward the disc. Very often the sculpture of the beak is obsolete; hinge always complete, with well developed teeth, often quite heavy; male and female shell in most cases absolutely undistinguishable.

Remarks: It is practically impossible to recognize this group by shell characters, although there are certain peculiar types of shell, which are found in this group alone. Simpson failed entirely to recognize the close affinity of the genera belonging to this group, and places them in three different divisions of his system, bringing his *Unio* and *Pleurobema* together with the *Anodonta*-group, with which there is no close relationship whatever, and removing *Tritogonia* entirely from them. The genera of Simpson's system belonging here cannot be maintained as defined by Simpson, and material changes will be necessary as will be shown hereafter.

2. The second group comprises the following genera of Simpson: *Strophitus*, *Anodonta*, *Anodontoides*, *Symphynota*, and *Alasmidonta*.

Here each ovisac of the gravid female is not formed by a whole water-tube, but only by a part of it, the middle one, which is separated from two lateral canals by a folding up of the epithelium of the septa. In addition, the ovisacs are closed above at the base of the marsupial gill, thus forming a completely closed sac within each water-tube. In one case (*Strophitus*) this sac is again divided into secondary compartments. The edge of the marsupial gill becomes adapted to the swelling of the gill in the breeding season, and gives way, the two laminæ drawing apart;

[16]This holds good only for the Pennsylvanian species examined by me. In exotic forms belonging to this group, the inner lamina may be connected with the abdominal sac (See Nautilus, 23, April, 1910, p. 139).

and there is heavy tissue at the edge capable of being stretched out. This causes a rounded or truncated edge in the charged marsupium. This peculiar structure of the marsupial gill is developed only in the gravid female, and is absent in the sterile female.

These characters are apparently connected with the prolonged breeding season, and the peculiar secondary water-tubes serve for the aëration of the embryos in the marsupium. The stretching of the edge of the gill is easily understood.

Other characters are the following: marsupial gills always extremely swollen and marsupium always formed by the outer gills alone in their whole length; supra-anal opening well separated from the anal; the separating connection of the margins of the mantle well developed, sometimes short, but normally somewhat longer, and even quite long, thus leaving only a short slit for the supra-anal; branchial opening well defined anteriorly; no papillæ or other special structures on the edge of the mantle in front of the branchial opening; inner lamina of inner gills free from the abdominal sac, more rarely more or less connected with it; glochidia very remarkable, and furnishing a very important character of this group. They are generally very large, subtriangular, in rare instances almost semicircular in shape, and are more or less pointed in the middle of the ventral margin, where they possess a peculiar spine or hook (this spine is undeveloped in very young glochidia). The glochidia are sometimes imbedded in well developed placentæ or placentulæ. Sometimes the placentæ are poorly developed, or the glochidia appear completely isolated. The discharge is by the natural channels and the anal opening, and these forms are bradytictic.

The essential characters of this group are found in the shape and structure of the marsupium, which represent adaptations to the extreme swelling of the latter, and to the long breeding season, for all forms belonging here are bradytictic. The formation of lateral water-canals in the marsupium undoubtedly is a device to provide proper aëration for the glochidia enclosed so long a time in the marsupium. Whether the special hooks of the glochidia are connected with a differentiation of function from that in the *Quadrula*-group is yet unknown.

The shell of the forms belonging to this group is never very heavy and solid, and never distinctly rounded, but it is more or less elongate, rather thin, often with distinctly colored epidermis (banded and rayed). The sculpture of the beak is of two types: either more or less distinctly double-looped, or concentric; in the latter case often very heavy. The hinge-teeth have a distinct tendency to become obsolete. They are present in some forms, but are then often of peculiar shape, and in others they exhibit all stages of reduction to complete disappearance.

The male and female shells are generally quite undistinguishable, only in rare cases is there a slight differentiation.

Remarks: The genera belonging here stand together in Simpson's system, but associated with others, which do not belong here, and the essential characters of this group have been entirely overlooked. Sterki has correctly recognized their natural affinity, relying chiefly upon the remarkable shape of the glochidium. But, as we have seen, there are additional characters in the gills of the gravid female, which are common to all these forms, which are so peculiar, and so strongly marked, that there cannot be the slightest doubt, that this is a natural group.

3. All the remaining genera form a third group, and are more closely allied to each other than to any one of the groups thus far discussed. This comprises the following of Simpson's genera: *Truncilla, Micromya, Lampsilis, Obovaria, Plagiola, Obliquaria, Cyprogenia,* and *Ptychobranchus.*

They all agree in that here again each ovisac is formed by only one water-tube, and that this remains simple. But we have here a special structure at the edge of the gills, which permits a bulging out of the ovisacs beyond the original edge of the gills, and this causes a projection of the marsupial gills beyond the original edge, indicated by the ends of the gill-filaments. The swelling of the marsupium takes place chiefly at and near the edge of the gill, and since near the base no swelling in a longitudinal direction is possible, the arrangement of the ovisacs often is fan-like, they being narrower and thinner near the base, and thicker (club-like) toward the edge. This necessarily causes a folding of the edge of the gill, which is most pronounced in one genus (*Ptychobranchus*), where the whole outer gill is used as marsupium. In all other genera it is only the posterior section of the outer gill, which serves as marsupium (sometimes only part of this section); and here the marsupium is almost kidney-shaped and forms only a single, irregular fold with the non-marsupial anterior part, and sometimes a smaller fold with a posterior non-marsupial section of the gill. The edge of the marsupial gill is peculiarly beaded, the beads corresponding to the protruding ovisacs, the furrows between them to the septa on the inside of the gill.

The marsupium is generally much swollen, and the ovisacs are rather large, and, toward the edge, rather sharply defined externally; supra-anal opening always well separated from the anal; the connection of the mantle generally short or of medium length, leaving a rather large supra-anal opening; only rarely is the latter small, or entirely closed; branchial opening well defined in front; anterior to it there may be no special structures, or such may be present in the shape of papillæ or flaps on the mantle edge; inner lamina of inner gill generally entirely connected with the abdominal sac, more rarely partly or almost entirely free.

Glochidia generally of medium size and normally of simple shape, semicircular or semielliptical, without spines; yet in certain forms peculiar glochidia are found (See p. 301). Placentæ more or less well developed, but often atrophied, so that the glochidia appear free. The discharge of the glochidia takes place in an unusual manner, through the edge of the marsupium.

The essential characters of this group (marsupium and edge of mantle) undoubtedly are connected with the prolonged breeding season (all these forms are bradytictic), and with the unusual manner of discharging the glochidia. The soft parts are built according to a special plan, which is adapted to this peculiar discharge, and facilitates the proper aëration of the glochidia during the long breeding season, but this latter adaptation is different from that seen in the *Anodonta*-group serving the same purpose.

Shape of the shell very variable, round and heavy, or more or less elongated and lighter. Color of epidermis dull or bright. Sculpture of beak generally more or less double-looped, more rarely concentric, often obsolete. Hinge mostly well developed, with strong teeth, rarely somewhat reduced. Male and female shells more or less differentiated, sometimes only very slightly, but in other cases the differences between the shells of the two sexes are very striking.

Remarks: The essential structure of the marsupium of this group has been entirely overlooked by Simpson. He, indeed, brings these forms together in his system, but groups them according to characters, which are rather unimportant. In addition, his generic divisions are not at all satisfactory, and need complete revision, as we shall see below. Sterki also has recognized the mutual affinity of these forms, but on account of the similarity of the glochidia to those of the genera of the first group (*Quadrula*, etc.), he brings them too near to the latter. The structure of the marsupium in this group is again so unique, that it alone suffices to sharply separate the group from all others.

I do not think there should be any doubt or hesitation in recognizing these groups as natural. The differences are such and so uniform, that we must regard them as fundamental. They concern in the first instance the *sexual apparatus*, and the development and specialization of the structures, which serve the physiological process of propagation, we are compelled to take as the surest indication of a phylogenetic progress within the group. One of the most important characters of the fresh-water shells, called *Najades*, is found in the way they take care of their young, not discharging the eggs directly into the water, but keeping them for a time in the gills; and it is only natural that this peculiar feature, after it had once developed, is further improved, complicated, and specialized.

All modifications of the gills are directly or indirectly correlated with the sexual apparatus, and besides a number of other characters of the soft parts as well as the hard parts are connected with it; in fact the sexual apparatus is the most important feature of the *Najades*. This is not at all astonishing; we find the same conditions in so many other groups of animals. Thus it is clear that a system founded upon these characters must be a natural one, and that it shou'd be fitted to furnish us the key for the proper understanding of the systematic relations.

Thus we are to regard the above three groups (excluding *Margaritana*) as so many natural divisions of the family UNIONIDÆ, which then, of course, should rank as subfamilies,[17]) namely: the UNIONINÆ, ANODONTINÆ, and LAMPSILINÆ. For *Margaritana* it is unquestionably best to create a new family, the MARGARITANIDÆ.

It is evident, even without the knowledge of certain details of the sexual apparatus, that the *Margaritanidæ* form the most primitive group of the *Najades*. The character of the gills surely indicates this, and also the character of the branchial and anal openings, although possibly the shell may not represent the most ancient type.

Of the *Unionidæ*, the *Unioninæ* are certainly more primitive than the other two subfamilies, as is evidenced by the simple character of the structure of the marsupial gills. The *Anodontinæ* and *Lampsilinæ* are more advanced, but they have advanced in different directions, and each has developed special features of the sexual apparatus. Generally speaking, the *Lampsilinæ* contain the most highly advanced types, as is shown by the restriction of the marsupium to a part of the outer gill, and by the strong expression of the sexual differentiation in the outer shell. Yet there are forms among the *Anodontinæ*, which show extremely complex structures (*Strophitus*), unparalleled in any other genus, and the peculiar glochidia of the *Anodontinæ* surely mark a high stage of development. The arrangement and sequence of the families and subfamilies would possibly be the best as given above; but we must not forget that, while, for instance, the *Lampsilinæ* show relations in the structure of the edge of the gill to the *Anodontinæ*, they more nearly approach the *Unioninæ* in the shape of the glochidia. This is, however, the usual difficulty in all our systematic arrangements.

[17]Simpson unites all these forms in one subfamily, *Unioninæ*, from which he distinguishes as a second subfamily the *Hyrianæ* (properly *Hyriinæ*), with the marsupium formed by the inner gills alone, and with radial beak sculpture. The conception of the latter subfamily on the part of Simpson is entirely wrong. Very little is known about their anatomy, but I recently have been able to investigate some of the genera, and find that some are really *Unioninæ* (in the new sense), while others rather agree with the family *Mutelidæ* (See Nautilus, 23, April, 1910, p. 139, and January, 1911). With regard to the sculpture of the beak, serious mistakes have been made. The shape of the marsupium certainly is important, but at present in many genera is unknown. The *Mutelidæ* are reported to possess a lasidium in place of the glochidium, but again the larvæ of many genera of these are entirely unknown. I hope to be able to contribute to the solution of this question in the near future, on the basis of a splendid collection representing the "*Hyriinæ*" from South America.

I think that the families and also the three subfamilies of the *Unionidæ* are *geologically rather old*, and we cannot say that one descended from the other. They probably go back to a common ancestral group, which probably stood somewhere between the present *Margaritanidæ* and *Unioninæ*. It is not my object, at present, to go into detail in this respect, and to discuss the phylogeny of the *Najades*. This will be possible only after a fuller knowledge is at hand of the exotic forms, and by studying also the fossil *Najades*. But I may here incidentally mention that I believe that these main groups probably go back to the Cretaceous, but the *Lampsilinæ* may be a little, but not much, younger. This is also expressed in the geographical distribution, the *Lampsilinæ* alone being restricted to North America (including Central America), while the others are also found in the Old World. But I shall leave this question for the present.

B. The Genera.

1. The *Margaritanidæ* consist solely of the genus *Margaritana*.

2. The *Unioninæ* contain the following genera of Simpson: *Tritogonia*, *Unio*, *Pleurobema*, *Quadrula*. With regard to *Tritogonia*, Sterki (Nautilus, 21, 1907, p. 48) was the first to point out that it possesses the marsupium attributed by Simpson to the genus *Quadrula*, and my own investigations have convinced me that this is quite correct, and that *Tritogonia* is a true *Quadrula*. The other three genera fall according to Simpson into two groups. In *Unio* and *Pleurobema* only the outer gills serve as the marsupium, while in *Quadrula* both outer and inner gills become charged with ova.

My investigations have shown that there are indeed a number of species, in which all four gills are marsupial, while there are others, in which this is true only of the outer gills. This is an absolutely constant character, and I have not seen a single instance in any species, where there was any variation in this respect. Thus it is evident, that this character, emphasized by Simpson, is important, and it is indeed, so far as I can see, the most important one which marks a division within this subfamily. Thus we must retain the genus *Quadrula* in the sense that it comprises those species, in which all four gills serve as marsupium. However, Simpson placed in the genus *Quadrula* a number of species, which according to my observations have the marsupium formed only by the outer gills. This he did, of course, because he did not know the marsupium. As long as we were unable to recognize the shape of the marsupium, unless we had gravid females, it was impossible to assign the proper place to any species, in which the gravid female was unknown. But since I have shown that the sex of any specimen may be

ascertained by the septa of the gills, and that we are able to make out the character of the marsupium also from the sterile female, it is now possible to properly place all species of which females are at hand. Thus I have ascertained, that the following forms of Simpson are true *Quadrulas: Q. subrotunda, kirtlandiana, rubiginosa, trigona, pustulosa, metanevra, cylindrica, undulata, plicata hippopæa,* and *Tritogonia tuberculata. Q. lachrymosa* also belongs here, judging from specimens obtained in Kansas and from the middle Ohio River.

Of other forms of Simpson's *Quadrula* which I have investigated the following proved to have only the outer gills built to receive eggs: *Q. tuberculata, coccinea, pyramidata, obliqua, cooperiana.* With the exception of the first these all fall under *Pleurobema,* in Simpson's sense, but it is somewhat different in the case of *Q. tuberculata.* Here we have additional characters, which have already been pointed out by Simpson, and which induced him to place this species in a separate subgenus, *Rotundaria.* The chief features are the absence of a supra-anal opening and the peculiar sculpture of the beak. The structure of the hinge and the color of the nacre are also rather peculiar, and there are so many distinctive characters in evidence, that I feel fully justified in elevating the subgenus *Rotundaria* to the rank of a genus.

All other forms with only the outer gills serving as marsupium should belong to the two genera *Pleurobema* and *Unio.* There are no differences whatever in their soft parts, and these two genera can be distinguished only by the characters of the shell. Looking over Simpson's elaborate diagnoses (they are rather descriptions), it is hard to find well-marked differential characters. The shape of the shell may be taken as the most important criterion. In *Pleurobema* it is quite solid, triangular, rhomboidal, or subovate, more or less distinctly oblique, that is to say, with the two axes giving the two principal dimensions (height and length) forming a distinct and sharp angle with each other. This causes the umbonal region, which is more or less elevated, to assume an anterior location in the shell. In *Unio* on the contrary the shell varies from oval to elongate, is straight, with the axes very nearly vertical to each other, with the result that the umbonal region is less elevated and less anterior. Further, in *Pleurobema* the color of the epidermis is from dark brown to light brown or olive, with prevalence of the lighter shades, and the color of the nacre is white or silvery, rarely lighter or darker pinkish or salmon-red, but never purple. In *Unio,* the epidermis is brown to black, very rarely lighter, with prevalence of the darker shades, and the nacre may be white, but more often assumes red to purple tints.[18]

[18]As will be shown elsewhere, the North American genus *Unio* should be separated from the typical European *Unio* (Type: *pictorum* Linnæus). For the former the name *Elliptio* Rafinesque 1819 is available.

The Pennsylvanian species placed under *Unio* are unquestionably more closely allied to each other than to those placed under *Pleurobema,* but there are other extralimital species, which cannot be so easily associated with this genus. Furthermore, we have several types included in the genus *Pleurobema* which are rather distinct, and which may be entitled to generic rank, unless we prefer to leave all these forms united in the old genus *Unio.* The Pennsylvanian material representing the species of this group is scarcely extensive enough to enable us to settle this question. There are a multitude of forms of *Unio* and *Pleurobema* in the central and southern parts of North America, many of which apparently form connecting links. Before these have been more closely studied, and before it has been positively ascertained that they belong in this group, it is futile to attempt a final classification of these forms. Thus I retain the main divisions (*Unio* and *Pleurobema*) introduced by Simpson, adding to the latter genus the species removed from *Quadrula.* With regard to *Q. cooperiana* it is absolutely certain that it stands close to another species placed by Simpson in *Pleurobema, P. æsopus,* and is still more closely allied to *P. cicatricosum.* With regard to *Q. coccinea, pyramidata,* and *obliqua,* this is not so evident, but I think that there are some southern types of *Pleurobema,* with which these should be associated.

I assume that *Quadrula* having four gills serving as marsupium, represents a more primitive stage than the others, where only the outer gills have this function and the corresponding structure. It appears, as a matter of course, that the differentiation between the gills, the inner serving exclusively the function of breathing, and the outer exclusively that of propagation, represents a higher stage of development than in those cases in which all gills serve both functions; and this is further supported by the fact that in certain species of *Quadrula* (*subrotunda, kirtlandiana, rubiginosa*) we have types, in which the swelling of the marsupium in the breeding season is so small, that the water-tubes and their contents remain subcylindrical, which undoubtedly is a primitive condition. The fact that the most primitive form, *Margaritana,* has also all four gills marsupial, further speaks for our assumption. Yet I cannot suppress the thought that the opposite opinion has something in its favor, and the evidence for this is furnished by the fundamental differentiation of the edge of the inner and outer gill, as is shown by my description of the peculiar furrow along the edge of the inner gill, which is absent in the outer gill. As stated above, I cannot surmise what the meaning of this feature is. It may be possible that it represents an old, primitive differentiation of the two gills, the edge of the outer gill indicating the original restriction of the function of propagation of this gill. Then, of course, we would have to assume that in *Quadrula*

this function spread secondarily to the inner gill. I must confess that this idea appears to me as unlikely, since it means a going back to a less specialized stage, two organs, each of which originally served a different function, now assuming both. The balance of evidence is, I think, in favor of the assumption made here, but the question is open to further study.

3. The *Anodontinæ.* Simpson's genera: *Strophitus, Anodonta, Anodontoides, Symphynota,* and *Alasmidonta* belong here. The definition of these according to shell characters, as given by Simpson, is rather satisfactory, and I merely suggest another arrangement of them. There is no question that *Strophitus,* in spite of the peculiarity of the marsupium, comes nearer to *Alasmidonta,* than to any other genus, which is chiefly shown by the heavy sculpture of the beak, and the tendency of the inner lamina of the inner gill to become united with the abdominal sac. On the other hand *Symphynota* and *Anodonta* are more closely allied, as is shown by the sculpture of the beak. *Anodontoides* is essentially an *Anodonta,* but with different sculpture of the beak. We apparently are dealing here with a number of types, which have developed independently from a common source, and of which each has preserved one or the other primitive character, while it is more advanced in other features. *Strophitus* is extreme in the structure of the marsupium; *Anodonta* is extreme in the reduction of the hinge-teeth. With regard to the hinge-teeth we observe that we have primitive types in *Alasmidonta heterodon,* and *Symphynota compressa* and *viridis;* yet they are again peculiarly transformed. The inner lamina of the inner gills is more primitive (free) in *Anodonta, Anodontoides,* and *Symphynota,* while a more advanced stage is observed in *Alasmidonta* and *Strophitus. Anodonta* represents an extreme stage in the development of the supra-anal opening. The following sequence possibly would be advisable: *Alasmidonta, Strophitus, Symphynota, Anodontoides, Anodonta.*

4. *Lampsilinæ.* The following genera of Simpson's "Synopsis" belong here: *Truncilla, Micromya, Lampsilis, Obovaria, Plagiola, Obliquaria, Cyprogenia, Ptychobranchus.* Some of them are very well defined, while others stand in need of a thorough revision.

First of all, *Ptychobranchus* stands by itself, on account of its very unique marsupium, the peculiarity of which is fully appreciated by Simpson. Yet, as we have seen, *Ptychobranchus* is truly *lampsiline,* for it has the characteristic structure of the edge of the marsupium. There is no question that it is the most primitive form in this subfamily, although possibly the present condition of the marsupium is not the original one.

Among the others we see that the structure of the marsupium is practically

alike; there are very few minor differences, but the genera, *Obliquaria* and *Cyprogenia*, stand out more prominently among them.[19] They possess a remarkably small number of ovisacs, which stand rather in the middle of the outer gill, and the shell also is peculiar in its shape and ornamentation. *Cyprogenia* is in addition distinguished by the great prolongation of the marsupium, which forces it to coil up within the shell. Thus these two genera are well defined.

As has been seen above, there is among the *Lampsilinæ* a further differentiation connected with the sexual apparatus, which, in my opinion, is of prime value. This is the development of special structures on the edge of the mantle in front of the branchial opening. Although some of these structures have been noticed by previous writers, no importance has been attached to them.

We have observed, that in the genera *Truncilla*, *Micromya*, and in certain species of *Lampsilis* such structures are present, while in other species of *Lampsilis*, as well as in *Obovaria*, *Plagiola*, *Obliquaria*, *Cyprogenia*, and *Ptychobranchus*, they are absent, or barely indicated. We have seen, that *Ptychobranchus*, *Obliquaria*, and *Cyprogenia* may be distinguished on other grounds. This leaves certain species of *Lampsilis* (*ligamentina*, *alata*, *gracilis*), and the genera *Obovaria* and *Plagiola* as a group, possessing a similar conformation of the edge of the mantle. *Plagiola*, *Obovaria*, and *Lampsilis ligamentina* are practically identical in the entire structure of the soft parts, and in the form of the shell they also stand rather close together. With regard to *Lampsilis ligamentina*, I do not see any reason why it should not be placed with *Obovaria;* in fact it fully agrees with Simpson's diagnosis of *Obovaria*, and could be grouped very well with *O. ellipsis*. *Plagiola* can be distinguished from *Obovaria* only by the characters of the shell, chief among which are the presence of a distinct posterior ridge and the peculiar markings of the epidermis. (In addition, *P. securis* has a peculiar glochidium, but the writer does not know whether this glochidium is found in other species of *Plagiola*.)

Lampsilis alata and *gracilis* have been placed by Simpson in a separate subgenus, *Proptera*, on account of the peculiarities of the shell (general shape and character of hinge-teeth). Sterki has proposed to elevate it to the rank of a genus on account of the odd glochidium of *L. alata*, assuming, that this shape is also found in the other species of *Proptera*. Since I have shown, that the glochidium of *L. gracilis* differs fundamentally from that of *L. alata*, and also from all other *Lampsilinæ*, we are forced to restrict the genus *Proptera* to those forms, which have a glochidium like *L. alata* (*purpurata*, *lævissima*), and should create a new

[19]Recently, Sept. 24, 1910, I found a gravid female of *Cyprogenia irrorata* in the Ohio River at Portsmouth, Scioto Co., Ohio, and had a chance to study its soft parts.

genus for *L. gracilis*. I propose here the name of *Paraptera* for it. *Paraptera* and *Proptera* are closely allied in the structure of the soft parts, and agree especially in the edge of the mantle.[20] They also have many similarities in the shell, and greatly differ in this respect from *Obovaria* and *Plagiola*.

The separation of the species would leave in the genus *Lampsilis* the following species: *parva, iris, nasuta, recta* (forming a group with papillæ on the edge of the mantle); and *ventricosa, ovata, multiradiata, cariosa, orbiculata* (with a flap on the edge of the mantle). But I also unite with this genus *Micromya fabalis*, which does not differ in any essential point from *Lampsilis*, and possesses on the edge of the mantle the characteristic papillæ of the first group of *Lampsilis*.

Lastly we have the genus *Truncilla*, which is not only characterized by the soft parts, as we have seen above, but more emphatically by the shape of the shell. Simpson's division of this genus into subgenera is well supported.

It is clear, that *Truncilla* and *Lampsilis* are the most advanced types of this subfamily, and that *Ptychobranchus* in the first line, and then *Obliquaria, Obovaria*, and *Plagiola* are rather primitive. *Cyprogenia, Paraptera*, and *Proptera* represent special modifications of this primitive type.

We thus obtain the following arrangement of the families, subfamilies, and genera of the *Najades* found in Pennsylvania. (Compare my Preliminary Report, 1910, p. 114.)

1. Family Margaritanidæ Ortmann (Nautilus, February, 1911).

Diaphragm incomplete, formed by the gills; posteriorly the outer lamina of the outer gills not connected with the mantle for a considerable distance; anterior end of the inner gills separated from the palpi by a gap;[21] branchial and anal openings ill-defined, and the latter not closed above; no supra-anal developed; gills without water-tubes, and with scattered interlamellar connections, which in certain places form irregular diagonal rows; marsupium formed by all four gills; larva a small, semicircular glochidium, without distinct hooks; shell elongated; sculpture of the beak concentric; hinge-teeth imperfect; epidermis blackish.

Genus **Margaritana** Schumacher.[22]

[20] I do not understand Simpson's description (1900, p. 567) of the edge of the mantle of *Proptera*, and have not seen anything which could be called a "thickened flap of the outer fold."

[21] This item should be inserted in the diagnosis on account of the different structure found in the *Mutelidæ* (See Nautilus, January and February, 1911).

[22] Certain writers (See Thiele, in Brauer, Suesswasserfauna Deutschlands, Heft 19, 1909, p. 32) consider *Margaritana* the type of the genus *Unio*, and call *Unio* by the name of *Lymnium* Oken 1815. This is not correct, as Simpson has already clearly shown (1900, p. 674, footnote 1).

2. Family UNIONIDÆ (d'Orbigny), Ortmann (Nautilus, February, 1911).

Diaphragm complete, formed by the gills; posteriorly the outer lamina of the outer gill connected with the mantle to its posterior end; anterior end of the inner gills separated from the palpi by a gap; branchial and anal openings sharply separated from one another by the diaphragm; anal opening very rarely not closed above and without supra-anal, generally closed and with a supra-anal opening (which very rarely may be obliterated); gills with water-tubes and distinct, continuous interlamellar septa, running parallel to the filaments. Marsupium in all four gills, or only in the outer gills; larva a glochidium. Shell of very variable shape; sculpture of the beak more or less reduced, of various types, but originally of the concentric or zig-zag pattern; hinge-teeth perfect or imperfect; epidermis plain or with color-markings.

1. Subfamily UNIONINÆ (Swainson) Ortmann.

Inner lamina of inner gills generally free from the abdominal sac (sometimes, in extralimital forms connected); supra-anal opening sometimes not separated from the anal, normally present, the closed part rather short; branchial opening well-defined; no papillæ or flaps on edge of mantle in front; marsupium formed by all four gills, or by the outer gills only; edge of marsupium always sharp and not distending; water-tubes not divided in the gravid female; glochidium semi-elliptic or semicircular, without spine; shell generally heavy and solid, rounded to elongated, mostly with dull-colored epidermis; sculpture of the beak generally rather indistinct, concentric, or pustulous, or with indications of double loops or zig-zag bars; hinge always complete, with rather strong teeth; generally no difference of sex shown in the shell.

GENERA

a^1. All four gills serving as marsupium; anal and supra-anal opening separated, but separation often deciduous; shell of various shapes, always rather heavy, outside smooth or with sculpturings.
Genus **Quadrula** Rafinesque.

a^2. Only the outer gills serving as marsupium.

b^1. Supra-anal not separated from the anal opening; sculpture of the beak consisting of numerous, fine, irregular corrugations; shell rounded; beak-cavities very deep; nacre dark violet or purple.
Genus **Rotundaria** Rafinesque.

b^2. Supra-anal opening separated from the anal; sculpture of the beak consisting of few, generally concentric ridges; shell rounded or elongated; beak-cavities of medium depth, or shallow.

c^1. Shell oblique, ovate, or rhomboidal, with prominent beaks, which are placed rather anteriorly; color of epidermis brown to light, generally not very dark, often with rays; nacre varying from light red to white.
Genus **Pleurobema** Rafinesque.

c^2. Shell ovate or elongate; beaks not very prominent, and not much produced; color of epidermis brown to black, only indistinctly rayed, if at all; nacre varying from white to deep purple, with the dark shades prevailing. Genus **Elliptio** Rafinesque.[2]

2. Subfamily Anodontinæ Ortmann.

Inner lamina of inner gill free from the abdominal sac or more or less connected with it, rarely entirely connected; supra-anal opening well separated from the anal, sometimes the connection of the mantle separating it from the anal is very long, and the supra-anal is quite short; branchial opening well defined, no papillæ or flaps in front of it on the edge of the mantle; marsupium formed by the outer gills in their whole length, distending, when charged, and the thickened tissue at the edge capable of stretching out in a direction transverse to the gill, but not beyond the edge (or only slightly so); water-tubes in the gravid female divided longitudinally into three tubes, with only the one in the middle used as an ovisac, and closed at the base of the gill; glochidium semicircular or triangular, with a spine (hook) in the middle of the ventral margin of each valve; shell generally not very heavy, often thin, never round, but more or less elongated; color of epidermis generally bright and with color markings; sculpture of the beak double-looped or concentric, in the latter case often extremely heavy; hinge rarely complete, and if so, of peculiar structure; generally there is a distinct tendency toward the reduction of the hinge-teeth, and often they are completely absent; sexual differences in the shell very rarely present.

Genera

a^1. Sculpture of the beak concentric, heavy; inner lamina of inner gills having a tendency to become united with the abdominal sac.

b^1. Shell with cardinal teeth; lateral teeth present or wanting; ovisac of each water-tube in the gravid female not subdivided; placentæ poorly developed, and glochidia practically free. Genus **Alasmidonta** Say.

b^2. Shell with the hinge-teeth obsolete; only a mere vestige of the cardinal teeth remaining; ovisac of each water-tube subdivided into a number of compartments, each containing a well developed placentula, running crosswise to the gill; placentulæ persistent till they are discharged. Genus **Strophitus** Rafinesque.

a^2. Sculpture of the beak generally double-looped, if concentric, not heavy; inner lamina of inner gills always free; ovisacs not subdivided.

b^1. Shell rather solid, lateral hinge-teeth more or less imperfect; cardinal teeth present, but of peculiar shape, sculpture of the beak more or less double-looped. Genus **Symphynota** Lea.

b^2. Shell thin; hinge edentulous, or with mere traces of cardinal teeth.

[23]See above p. 330, footnote. The European genus *Unio* Retzius, although similar in anatomical detail, differs in shape and color of shell, and chiefly in beak sculpture (wavy, zig-zag or double looped) and glochidia. The type species of *Elliptio* is *U. crassidens* Lamarck.

c^1. Sculpture of the beak concentric, not heavy; supra-anal about as long as the united part of the margin of the mantle, which separates it from the anal opening.

Genus **Anodontoides** Simpson.

c^2. Sculpture of the beak generally double-looped; supra-anal small, widely separated from the anal opening. Genus **Anodonta** Lamarck.[24]

3. Subfamily Lampsilinæ Ortmann.

Inner lamina of inner gills rarely more or less free from the abdominal sac, generally connected with it throughout; supra-anal opening separated from the anal, rarely entirely closed; branchial opening well defined; edge of the mantle in front of the branchial opening smooth to crenulated, or with peculiar papillæ or a flap; marsupium rarely formed by the whole outer gill, generally only by or within the posterior part of the outer gill; edge of marsupium, when charged, distending, and bulging out beyond the original edge of the gill, generally assuming a beaded appearance; water-tubes simple in the gravid female; glochidium semi-circular or semi-elliptic, without spine, rarely celt-shaped and with two spines; shell heavy or lighter, rounded, or oval, to elongate; color of epidermis rarely dull, mostly bright, with color markings; sculpture of the beak generally double-looped, but often obsolete, more rarely concentric; hinge generally complete, with well-developed teeth, which only in rare cases show a tendency to become reduced; sexual differences more or less noticeable in the shell, often very strongly expressed.

Genera

a^1. Whole outer gill serving as marsupium, its edge thrown into a number of folds.

Genus **Ptychobranchus** Simpson.

a^2. Marsupium located in the posterior part of the outer gill, and projecting considerably beyond its original edge.

b^1. Inner edge of mantle in front of branchial opening smooth, crenulated, or with few and weak teeth, but without papillæ or flaps; male and female shell differing only slightly, or hardly at all.

c^1. Shell rounded, with surface sculpturings; marsupium consisting of comparatively few ovisacs, located near the centre of the outer gill.

d^1. A row of large knobs on each valve; marsupium projecting beyond the edge of the gill, not coiled up. Genus **Obliquaria** Rafinesque.

d^2. Sculpture of the surface nodular; marsupium projecting immensely beyond the edge of the gill, and coiled up spirally. Genus **Cyprogenia** Agassiz.

c^2. Shell rounded, oval, or compressed, without surface sculpture; marsupium large, kidney-shaped, occupying a large portion of the posterior part of the outer gill.

d^1. Shell solid, rounded, ovate or triangular, more or less swollen; if compressed, not winged.

[24]European writers (See Thiele in Brauer, Suesswasserfauna Deutschlands, Heft 19, 1909, p. 32) recently use *Anodontites* Bruguière, 1792, for *Anodonta* Lamarck 1799. This is entirely wrong. The type of *Anodontites* is *A. crispata* Bruguière a South American shell, belonging to *Glabaris* Gray 1847. Of course, *Anodontites* has the priority over *Glabaris*, and should be used in its place.

e^1. Shell rounded or ovate, without distinct posterior ridge. Color of epidermis dull, without color-markings, or simply with rays. Glochidia normal in shape and size.
Genus **Obovaria** Rafinesque.

e^2. Shell ovate or triangular, with a distinct, and often sharp posterior ridge; epidermis painted with broken rays, forming a pattern of lunate, squarish, or arrow-shaped marks; glochidia (in one species at least) rather large and with gaping margins.
Genus **Plagiola** Rafinesque.

d^2. Shell not very solid, or thin, ovate, more or less compressed and winged along the dorsal margin (at least when young).

e^1. Glochidia of normal shape, but of unusually small size. Genus **Paraptera** gen. nov.[25]

e^2. Glochidia celt-shaped, with two spines on each valve, with gaping margins.
Genus **Proptera** Rafinesque.

b^2. Inner edge of mantle in front of the branchial opening, chiefly in the female, differentiated by papillæ or flaps, and sometimes not parallel to the outer edge; male and female shells distinct, generally very markedly so.

c^1. Inner edge of mantle essentially parallel to the outer edge, with papillæ or flaps; shell ovate or elongate, the postbasal region of the female somewhat swollen and more rounded than in the male.
Genus **Lampsilis** Rafinesque.

c^2. Inner edge of mantle in the female in front of the branchial opening not parallel to the outer edge, but more or less remote from it, with papillæ; shell ovate or triangular, the postbasal region of the female very strongly inflated and projecting, giving to the whole shell an entirely different shape from that of the male. Genus **Truncilla** Rafinesque.

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[25]Type *P. gracilis* (Barnes).

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EXPLANATION OF PLATE LXXXVI.

Horizontal cross-sections through the gills of *Unionidæ,* to show structure of water-tubes, ovisacs, and septa, in the males, sterile and gravid females.

All photographs taken with Bausch & Lomb 1 inch objective. None of the figures has been retouched.

Fig. 1. *Quadrula subrotunda* (Lea) *Male.*—Allegheny River, Kelly, Armstrong County, June 22, 1909. Cat. No. 61.4400. Specimen 199.
1*a*. *Left inner gill.* 1*b*. *Left outer gill.*

Fig. 2. *Quadrula subrotunda* (Lea) *Female, sterile.*—Allegheny River, Kelly, Armstrong County, Sept. 5, 1907. Cat. No. 61.3083. Specimen 5.
1*a*. *Left inner gill.* 2*a*. *Left outer gill.*

Fig. 3. *Quadrula subrotunda* (Lea) *Female, gravid* (*eggs*).—Allegheny River, Kelly, Armstrong County, June 22, 1909. Cat. No. 61.4399. Specimen 7.
3*a*. *Right inner gill.* 3*b*. *Right outer gill.*

Fig. 4. *Quadrula tuberculata* (Barnes). *Female, sterile.* Mahoning River, Mahoningtown, Lawrence County, Aug. 4, 1908. Cat. No. 61.3574. Specimen 34.
4*a*. *Right inner gill.* 4*b*. *Right outer gill.*

Fig. 5. *Elliptio gibbosus* (Barnes) *Male.*—Little Beaver Creek, Enon Valley, Lawrence County, May 11, 1907. Cat. No. 61.2186. Specimen 54.
5*a*. *Left inner gill.* 5*b*. *Left outer gill.*

Fig. 6. *Elliptio gibbosus* Barnes. *Female, gravid* (*eggs*). Allegheny River, Templeton, Armstrong County, Aug. 13, 1907. Cat. No. 61.2963. Specimen 56.
6*a*. *Left inner gill.* 6*b*. *Left outer gill.*

Fig. 7. *Strophitus edentulus* (Say) *Female, sterile.* Allegheny River, Templeton, Armstrong County, Aug. 4, 1909. Cat. No. 61.4150. Specimen 117.
7*a*. *Left inner gill.* 7*b*. *Left outer gill.*

Fig. 8. *Strophitus edentulus* (Say) *Female, gravid, young* (*eggs*), *beginning of period of gravidity.* Conococheague Creek, Greencastle, Franklin, County, Sept. 6, 1909. Cat. No. 61.4160. Specimen 112.
Left outer gill.

Fig. 9. *Strophitus edentulus* (Say) *Female, gravid* (*eggs*), *a little more advanced than fig. 8.* Cush-Cushion Creek, Green Township, Indiana County, July 11, 1908. Cat. No. 61.3627. Specimen 109.
Left outer gill.

Fig. 10. *Strophitus edentulus* (Say) *Female, sterile, very young* (*shell 17 mm. long*). Crooked Creek, Rosston, Armstrong County, Aug. 3, 1909. Cat. No. 61.4148. Specimen 230.
10*a*. *Left inner gill.* 10*b*. *Left outer gill.*

1a

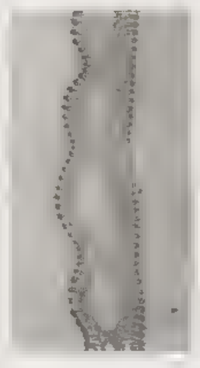
1b

2a

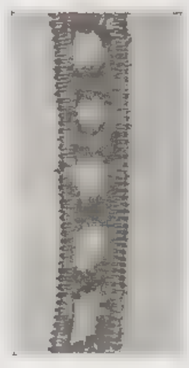
2b

3a

3b


5a

5b


4a

4b

6a

6b

7a

7b

8

9

10a

10b

11a

11b

12a

12b

13a

13b

14a

14b

15

16

SECTIONS OF GILLS

Fig. 11. *Symphynota viridis* (Conrad) *Probably hermaphrodite, gravid, very young (shell 31 mm. long) (with eggs and young glochidia).* Great Tonoloway Creek, Thompson Township, Fulton County, Sept. 5, 1909. Cat. No. 61.4221. Specimen 235.
11*a*. *Left inner gill.* 11*b*. *Left outer gill.*

Fig. 12. *Symphynota costata* (Rafinesque) *Female, gravid, discharging posteriorly (glochidia).* Ten Mile Creek, Amity, Washington County, April 22, 1908. Cat. No. 61.3303. Specimen 82.
12*a*. *Left inner gill.* 12*b*. *Left outer gill.*

Fig. 13. *Anodonta grandis gigantea* (Lea) *Male, young (shell 37 mm. long).* Pond, Harmarville, Allegheny County, Oct. 10, 1908. Cat. No. 61.3668. Specimen 231.
13*a*. *Left inner gill.* 13*b*. *Left outer gill.*

Fig. 14. *Anodonta grandis gigantea* (Lea) *Female, sterile, young (shell, 46 mm. long).* Pond, Harmarville, Allegheny County, Oct. 10, 1908. Cat. No. 61.3668. Specimen 236.
14*a*. *Right inner gill.* 14*b*. *Right outer gill.*

Fig. 15. *Anodonta grandis* Say. *Female, gravid (eggs), beginning of gravidity.* Conneaut Lake, northeast shore, Crawford County, Aug. 8, 1908. Cat. No. 61.3657. Specimen 203.
Left outer gill.

Fig. 16. *Anodonta grandis gigantea* (Lea) *Female, gravid (glochidia), fully charged.* Pond, Harmarville, Allegheny County, Oct. 10, 1908. Cat. No. 61.3668. Specimen 4.
Left outer gill (one lamina only).

EXPLANATION OF PLATE LXXXVII.

Horizontal (figs. 1–10) and *vertical* (figs 11–16) *cross-sections* through gills of *Najades*, to show structure of water-tubes, ovisacs, and septa, in the males, sterile and gravid females, and to show structure of the edge of the gills.

All photographs taken with Bausch & Lomb 1 inch objective. None has been retouched.

Fig. 1. *Ptychobranchus phaseolus* (Hildreth) *Male.* Loyalhanna River, Idlepark, Westmoreland County, Sept. 21, 1907. Cat. No. 61.3035. Specimen 119.
1*a*. *Left inner gill.* 1*b*. *Left outer gill.*

Fig. 2. *Ptychobranchus phaseolus* (Hildreth) *Female, sterile.* Raccoon Creek, New Sheffield, Beaver County, June 30, 1908. Cat. No. 61.3275. Specimen 123.
Left outer gill.

Fig. 3. *Ptychobranchus phaseolus* (Hildreth) *Female, gravid* (*eggs*). Loyalhanna River, Idlepark, Westmoreland County, Sept. 21, 1907. Cat. No. 61.3035. Specimen 120.
Left outer gill.

Fig. 4. *Plagiola securis* (Lea) *Male.* Allegheny River, Kelly, Armstrong County, Sept. 5, 1907. Cat. No. 61.3029. Specimen 127.
4*a*. *Left inner gill.* 4*b*. *Left outer gill.*

Fig. 5. *Plagiola securis* (Lea) *Female, gravid* (*glochidia*). Ohio River, Cooks Ferry, Beaver County, Sept. 10, 1908. Cat. No. 61.3565. Specimen 129.
Left outer gill.

Fig. 6. *Paraptera gracilis* (Barnes) *Female, sterile.* Ohio River, Industry, Beaver County, Sept. 8, 1908. Cat. No. 61.3549. Specimen 137.
Left outer gill.

Fig. 7. *Lampsilis iris* (Lea) *Female, sterile.* Presque Isle Bay, Lake Erie, Erie, Erie County, May 22, 1909. Cat. No. 61.4090. Specimen 144.
Left outer gill.

Fig. 8. *Lampsilis recta* (Lamarck) *Male.* Cheat River, Cheat Haven, Fayette County, Sept. 16, 1907. Cat. No. 61.3020. Specimen 149.
8*a*. *Left inner gill.* 8*b*. *Left outer gill.*

Fig. 9. *Lampsilis recta* (Lamarck) *Female, sterile.* Cheat River, Cheat Haven, Fayette County, July 10, 1908. Cat. No. 61.3509. Specimen 246.
Left outer gill.

Fig. 10. *Lampsilis ventricosa* (Barnes) *Female, sterile.* Little Beaver Creek, Enon Valley, Lawrence County, May 11, 1907. Cat. No. 61.2144. Specimen 168.
Left outèr gill.

Fig. 11. *Margaritana margaritifera* (Linnæus). Indian Run, Rene Mont, Schuylkill County, May 4, 1909. Cat. No. 61.4272. Specimen 200.

1a

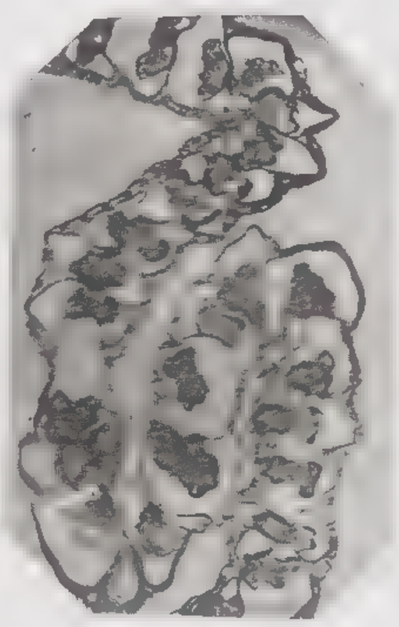
1b

2

4a

4b

6



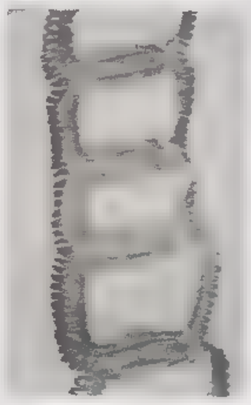
3

5

7

8a

8b



9

10

11a

11b

12a

12b

13a

13b

14a

14b

15a

15b

16a

16b

SECTIONS OF GILLS

11*a*. *Left inner gill.* 11*b*. *Left outer gill.*

Fig. 12. *Quadrula undulata* (Barnes) *Male.* Mahoning River, Mahoningtown, Lawrence County, Sept. 2, 1907. Cat. No. 61.3067. Specimen 17.

12*a*. *Right inner gill.* 12*b*. *Right outer gill.*

Fig. 13. *Quadrula undulata* (Barnes) *Female, sterile.* Mahoning River, Mahoningtown, Lawrence County, Sept. 2, 1907. Cat. No. 61.3067. Specimen 195.

13*a*. *Left inner gill.* 13*b*. *Left outer gill.*

Fig. 14. *Quadrula undulata* (Barnes) *Female, gravid* (*eggs*). Shenango River, Linesville, Crawford County, June 19, 1909. Cat. No. 61.4339. Specimen 16.

14*a*. *Right inner gill.* 14*b*. *Right outer gill.*

Fig. 15. *Pleurobema æsopus* (Green) *Male.* Allegheny River, Kelly, Armstrong County, Sept. 5, 1907. Cat. No. 61.3064. Specimen 194.

15*a*. *Left inner gill.* 15*b*. *Left outer gill.*

Fig. 16. *Pleurobema æsopus* (Green) *Female, gravid* (*eggs*). Allegheny River, Kelly, Armstrong County, June 22, 1909. Cat. No. 61.4333. Specimen 38.

16*a*. *Left inner gill.* 16*b*. *Left outer gill.*

EXPLANATION OF PLATE LXXXVIII.

Vertical (figs. 1–5, 10, 12–18, 20, 21) and *longitudinal* (figs. 6–9, 11, 19) *cross-sections* through the gills of *Unionidæ*, to show structure of ovisacs, septa, and edges of gills in males, sterile and gravid females.

All photographs taken with Bausch & Lomb 1 inch objective. None has been retouched.

Fig. 1. *Elliptio gibbosus* (Barnes) *Female, gravid (eggs).* Allegheny River, Templeton, Armstrong County, Aug. 13, 1907. Cat. No. 61.2963. Specimen 56 (Same as pl. LXXXVI, fig. 6).
Left outer gill.

Fig. 2. *Alasmidonta undulata* (Say) *Female, gravid (eggs), beginning of gravidity.* West Branch Mahantango Creek, Richfield, Juniata County, July 18, 1908. Cat. No. 61.3713. Specimen 75.
2*a*. *Right inner gill.* 2*b*. *Right outer gill.*

Fig. 3. *Alasmidonta undulata* (Say) *Female, gravid (glochidia) fully charged.* Schuylkill Canal, Manayunk, Philadelphia County, April 24, 1909. Cat. No. 61.4240. Specimen 206.
3*a*. *Base of left outer gill.* 3*b*. *Edge of left outer gill.*

Fig. 4. *Strophitus edentulus* (Say) *Female, sterile.* Allegheny River, Templeton, Armstrong County, Aug. 4, 1909. Cat. No. 61.4150. Specimen 117 (Same as Pl. LXXXVI, fig. 7).
Right outer gill.

Fig. 5. *Strophitus edentulus* (Say) *Female, gravid (glochidia), fully charged.* Newmans Branch, Wadsworth, Butler County, April 17, 1908. Cat. No. 61.3276. Specimen 201.
Left outer gill.

Fig. 6. *Strophitus edentulus* (Say) Same specimen as fig. 4.
Left outer gill.

Fig. 7. *Strophitus edentulus* (Say) *Female, gravid (eggs), beginning of gravidity.* Allegheny River, Templeton, Armstrong County, Aug. 4, 1909. Cat. No. 61.4150. Specimen 116.
Left outer gill.

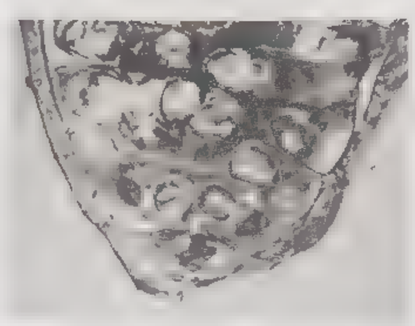
Fig. 8. *Strophitus edentulus* (Say) *Female, gravid (glochidia), more advanced.* Shenango River, Linesville, Crawford County, Oct. 10, 1907. Cat. No. 61.3118. Specimen 202.
Left outer gill.

Fig. 9. *Strophitus edentulus* (Say) Same specimen as fig. 5.
Left outer gill.

2a

2b

3a



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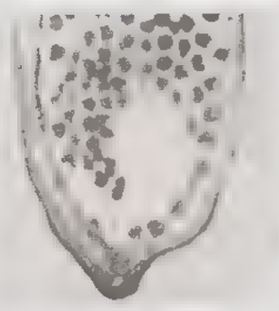
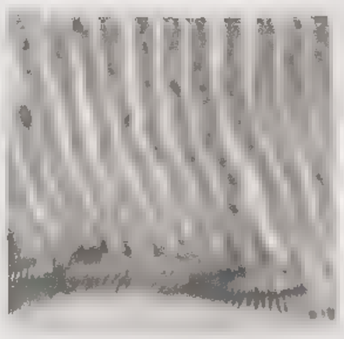


1

3b

4



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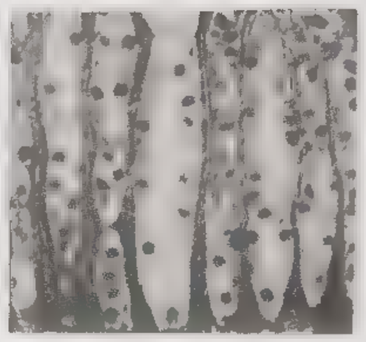

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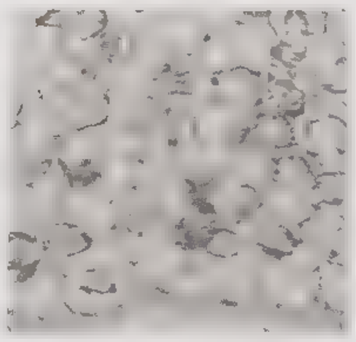

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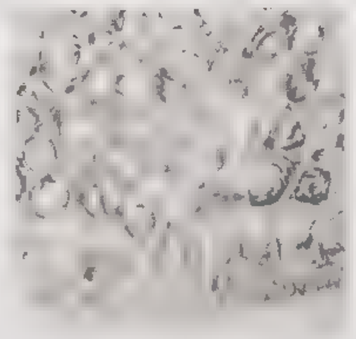


9

10

12a

12b

11

13

14

19

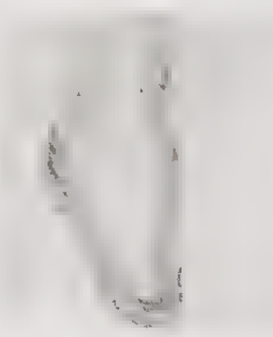
15

17

18

20

16



21

SECTIONS OF GILLS

Fig. 10. *Symphynota costata* (Rafinesque) *Female, gravid (young glochidia).* Loyalhanna River, Ligonier, Westmoreland County, Aug. 3, 1906. Cat. No. 61.1819. Specimen 205.
Left outer gill.

Fig. 11. *Anodonta grandis gigantea* (Lea) *Female, gravid (glochidia).* Pond, Harmarville, Allegheny County, Oct. 10, 1908. Cat. No. 61.3668. Specimen 4 (Same as Pl. LXXXVI, fig. 16).
Posterior part of base of right outer gill.

Fig. 12. *Ptychobranchus phaseolus* (Hildreth) *Male.* Neshannock Creek, Leesburg, Mercer County, Oct. 17, 1907. Cat. No. 61.3114. Specimen 183.
12*a*. *Left inner gill.* 12*b*. *Left outer gill.*

Fig. 13. *Ptychobranchus phaseolus* (Hildreth) *Female, sterile.* Presque Isle Bay of Lake Erie, Erie, Erie County, May 22, 1909. Cat. No. 61.4123. Specimen 214.
Left outer gill.

Fig. 14. *Ptychobranchus phaseolus* (Hildreth) *Female, gravid (eggs).* Mahoning River, Mahoningtown, Lawrence County, Sept. 2, 1907. Cat. No. 61.3032. Specimen 247.
Left outer gill.

Fig. 15. *Obovaria ligamentina* (Lamarck) *Female, sterile.* Cheat River, Cheat Haven, Fayette County, Sept. 16, 1907. Cat. No. 61.3013. Specimen 156.
Right outer gill.

Fig. 16. *Paraptera gracilis* (Barnes) *Female, sterile, but just discharged.* Ohio River, Industry, Beaver County, July 11, 1909. Cat. No. 61.4111. Specimen 210.
Left outer gill.

Fig. 17. *Lampsilis luteola* (Lamarck) *Female, sterile.* Little Mahoning Creek, Goodville, Indiana County, May 25, 1905. Cat. No. 61.1760. Specimen 159.
Left outer gill.

Fig. 18. *Lampsilis luteola* (Lamarck) *Female, gravid, discharging glochidia.* Ten-Mile Creek, Amity, Washington County, April 22, 1908. Cat. No. 61.3243. Specimen 207.
Left outer gill.

Fig. 19. *Lampsilis cariosa* (Say) *Female, sterile.* Delaware River, Yardley, Bucks County, April 24, 1908. Cat. No. 61.3417. Specimen 166.
Left outer gill.

Fig. 20. *Lampsilis multiradiata* (Lea) *Female, gravid, discharging glochidia.* Little Beaver Creek, Darlington, Beaver County, Aug. 9, 1907. Cat. No. 61.2921. Specimen 163.
Left outer gill.

Fig. 21. *Truncilla perplexa rangiana* (Lea) *Female, sterile.* Allegheny River, Godfrey, Armstrong County, Aug. 10, 1909. Cat. No. 61.3978. Specimen 173.
Left outer gill.

EXPLANATION OF PLATE LXXXIX.

Glochidia of *Unionidæ*.

All photographs taken with Bausch & Lomb two-thirds inch objective. In figs. 1, 2, and 4, some of the outlines of the glochidia have been intensified.

Fig. 1. *Quadrula subrotunda kirtlandiana* (Lea). Mahoning River, Mahoningtown, Lawrence County, Aug. 2, 1907. Cat. No. 61.2977. Specimen 9.

Fig. 2. *Quadrula rubiginosa* (Lea). Crooked Creek, Rosston, Armstrong County, Aug. 3, 1909. Cat. No. 61.4366. Specimen 217.

Fig. 3. *Quadrula undulata* (Barnes). Pymatuning Creek, Pymatuning Township, Mercer County, July 8, 1909. Cat. No. 61.4340. Specimen 15.

Fig. 4. *Pleurobema obliquum coccineum* (Conrad). Slipperyrock Creek, Wurtemberg, Lawrence County, July 4, 1909. Cat. No. 61.4385. Specimen 19.

Fig. 5. *Pleurobema clava* (Lamarck). Neshannock Creek, Eastbrook, Lawrence County, June 18, 1908. Cat. No. 61.3335. Specimen 40.

Fig. 6. *Elliptio crassidens* (Lamarck). Allegheny River, Kelly, Armstrong County, June 22, 1909. Cat. No. 61.4297. Specimen 52.

Fig. 7. *Elliptio gibbosus* (Barnes). Neshannock Creek, Eastbrook, Lawrence County, June 18, 1908. Cat. No. 61.3331. Specimen 57.

Fig. 8. *Alasmidonta heterodon* (Lea). Schuylkill Canal, Manayunk, Philadelphia County, April 24, 1909. Cat. No. 61.4250. Specimen 70.

Fig. 9. *Alasmidonta undulata* (Say). Crooked Creek, Tioga, Tioga County, Aug. 19, 1909. Cat. No. 61.4242. Specimen 76.

Fig. 10. *Symphynota compressa* Lea. Conneaut Outlet, Conneaut Lake, Crawford County, May 14, 1908. Cat. No. 61.3297. Specimen 90.

Fig. 11. *Symphynota complanata* (Barnes). Conneaut Outlet, Conneaut Lake, Crawford County, May 14, 1908. Cat. No. 61.3315. Specimen 80.

Fig. 12. *Anodontoides ferussacianus* (Lea). Shenango River, Linesville, Crawford County, Oct. 10, 1907. Cat. No. 61.3127. Specimen 93.

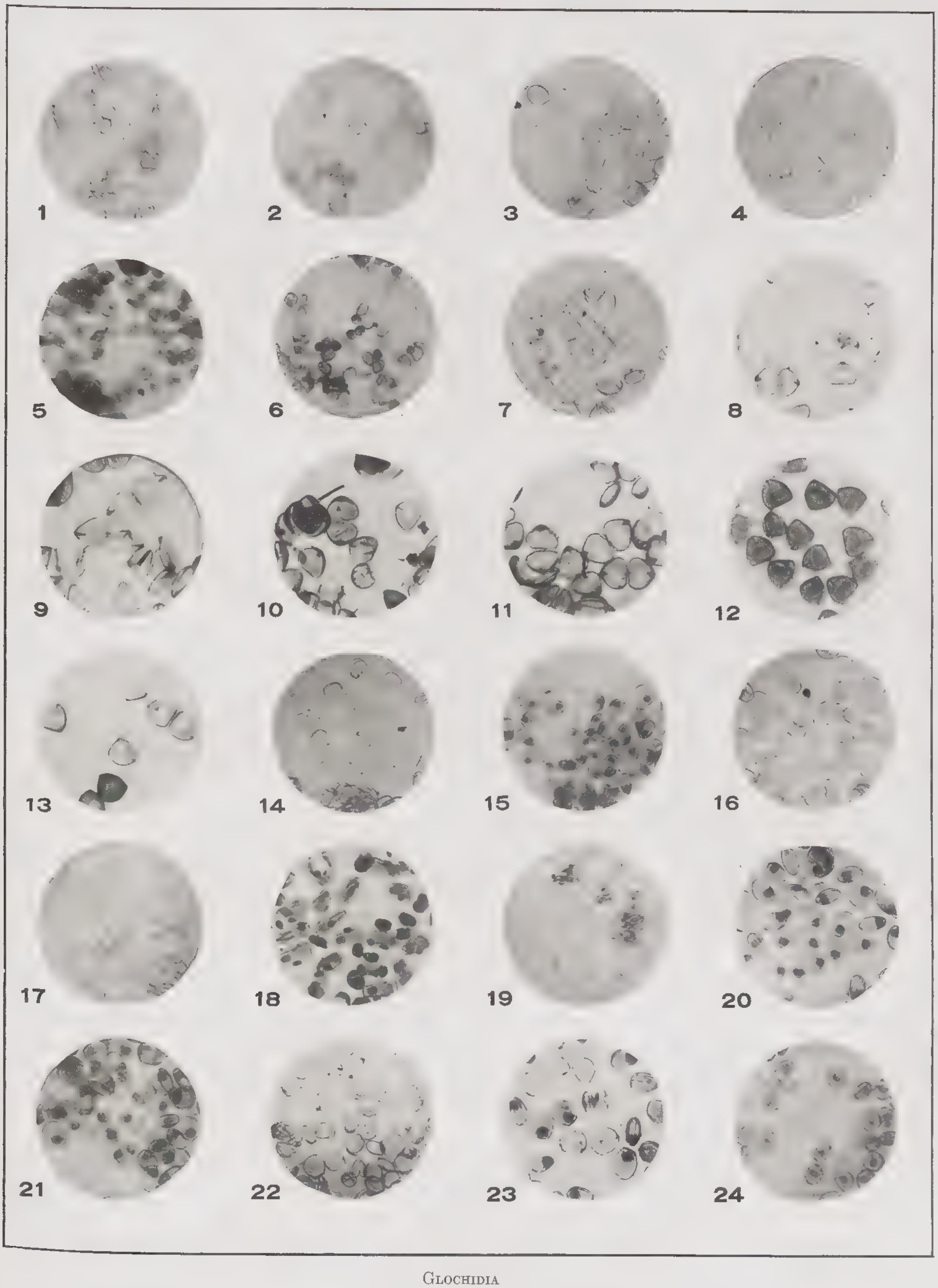
Fig. 13. *Anodonta imbecillis* (Say). Leboeuf Creek, Waterford, Erie County, Sept. 14, 1909. Cat. No. 61.4178. Specimen 102.

Fig. 14. *Ptychobranchus phaseolus* (Hildreth). Slipperyrock Creek, Rose Point, Lawrence County, Oct. 23, 1907. Cat. No. 61.3116. Specimen 218.

Fig. 15. *Obovaria circulus* (Lea). Crooked Creek, Creekside, Indiana County, May 27, 1908. Cat. No. 61.3269. Specimen 133.

Fig. 16. *Obovaria ligamentina* (Lamarck). Allegheny River, Kelly, Armstrong County, Oct. 24, 1907. Specimen 157.

Fig. 17. *Plagiola securis* (Lea). Ohio River, Industry, Beaver County, Sept. 23, 1908. Cat. No. 61.3567. Specimen 219.



GLOCHIDIA

Fig. 18. *Proptera alata* (Say). Ohio River, Industry, Beaver County, Aug. 29, 1908. Cat. No. 61.3538. Specimen 141.

Fig. 19. *Paraptera gracilis* (Barnes). Ohio River, Industry, Beaver County, July 11, 1909. Cat. No. 61.4111. Specimen 138.

Fig. 20. *Lampsilis iris* (Lea). Conneaut Creek, West Springfield, Erie County, May 23, 1909. Cat. No. 61,4091. Specimen 145.

Fig. 21. *Lampsilis recta* (Lamarck). Allegheny River, Godfrey, Armstrong County, July 23, 1907. Cat. No. 61.2935. Specimen 151.

Fig. 22. *Lampsilis orbiculata* (Hildreth). Ohio River, Industry, Beaver County, Sept. 23, 1908. Cat. No. 61.3500. Specimen 154.

Fig. 23. *Lampsilis ventricosa* (Barnes). Little Beaver Creek, Enon Valley, Lawrence County, May 11, 1907. Cat. No. 61.2144. Specimen 169.

Fig. 24. *Truncilla triquetra* Rafinesque. Allegheny River, Kelly, Armstrong County, Sept. 27, 1907. Cat. No. 61.2985. Specimen 178.

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PART I.

FISHES FROM THE UPPER EOCENE OF MONTE BOLCA.

BY CHARLES R. EASTMAN.

PITTSBURGH.

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VOL. IV. NO. 7.

CATALOG OF FOSSIL FISHES IN THE CARNEGIE MUSEUM.

Part I. Fishes from the Upper Eocene of Monte Bolca.

By Charles R. Eastman.

Introduction.

In the summer of 1903, the Carnegie Museum became enriched through the generosity of its founder with a magnificent collection of fossil remains, which, as regards the great group of Vertebrata, is without doubt the largest, most important, and most valuable assemblage ever brought together by a private individual in Europe, and rivals many of the more notable gatherings of fossil vertebrates in the public museums of the world.

This splendid acquisition, long coveted by American and foreign institutions, was the famous Bayet Collection, amassed after years of patient effort and very great expenditure by Baron Ernst de Bayet of Brussels, who for a long time was the Secretary of the late King Leopold of Belgium. A brief summary of the contents of this wonderful collection, a mere *coup d'œil*, as it were, of the riches which it presented at first inspection, was contributed by Dr. W. J. Holland to *Science* for June 19, 1903, and its installation in the Carnegie Museum was duly recorded in the Annual Report of the same institution for that year.[1] Some of the fossil avian remains in the collection were described in the second volume of the Memoirs of the Carnegie Museum, but with the completion of that paper systematic investigation of the great wealth of material contained in the Bayet Collection was temporarily suspended. Recently, however, the present writer was invited to undertake the difficult and important task of classifying and arranging the fossil fishes contained therein, and the present article may be considered as preliminary to more detailed contributions based upon the collection which may be made in the future.

[1] See also J. B. Hatcher; Vertebrate Paleontology at the Carnegie Museum (*Science*, n. s., Vol. XVIII, p. 569).

Some time was spent during the early summer of the year 1910 in making a preliminary survey and general inventory of the collection of fossil fishes as a whole, after which two large suites of specimens were set aside to serve as material for detailed investigation, the results of which will probably be incorporated in special monographs to be published either independently by the Carnegie Museum, or in coöperation with the Museum of Comparative Zoölogy at Cambridge, Massachusetts. One of these suites consists of fishes from the Upper Eocene of Monte Bolca, and the other of fishes from the Upper Jura of Solenhofen. Preliminary to the preparation of more elaborate papers based upon this material, it seemed desirable to Dr. Holland to publish systematic catalogs of the specimens from Monte Bolca and Solenhofen, which would serve the purpose of making known to ichthyologists and others interested in these groups the extent and variety of material which is represented in the Carnegie Museum; and also of placing on record, so as to be immediately available, any special notes, comments, or observations in regard to various specimens which might be found to possess unusual interest, or to elucidate new or imperfectly known features which from the point of view of distribution or otherwise might appear noteworthy.

In response to this suggestion of Dr. Holland, the present Catalog of Upper Eocene Fishes from Monte Bolca has been drawn up, its general plan and arrangement following somewhat closely the admirable model set by Dr. A. S. Woodward in his "*Catalogue of Fossil Fishes in the British Museum*"; due account being taken, however, of recently proposed changes in the classification. In some cases generic and family diagnoses have been amended in the light of fresh discoveries. Also, by way of affording a comparative estimate of the extent of the resources possessed by the Carnegie Museum, the actual number of representatives of various rare species preserved in the British and Carnegie Museums are set down side by side. No invidious comparison is thereby intended, but it seems proper to the writer to call attention to the fact that the western world has acquired through the generosity of Mr. Carnegie a paleontological collection which could not possibly be duplicated except at enormous expenditure of both money and time, and which in some respects rivals at least one of the great collections of the Old World. The student on this side of the Atlantic has therefore at his command unsurpassed facilities for reference and investigation.

The following contribution is a systematic account of the material in the Museum representing the Eocene fishes from Monte Bolca. A similar catalog of the Jurassic fishes from Solenhofen is in preparation. For references to the principal literature dealing with the ichthyic fauna of the Eocene of northern Italy

one may consult a contribution by the present writer published in the Bulletin of the Museum of Comparative Zoölogy for June, 1904 (Vol. XLVI, No. 1). It will be sufficient merely to indicate here the names of the principal contributors to this special literature since the time of Louis Agassiz. These are, in chronological order, Jacob Heckel, Rudolf Kner, Franz Steindachner, Raffaele Molin, Abramo Massalongo, Paolo Lioy, Achille de Zigno, Francesco Bassani, Wladislaw Szajnocha, Carl Gorganovič-Kramberger, Otto Jaekel, A. Smith Woodward, and Rudolf Cramer.

In conclusion it is proper to remark that the writer has taken the liberty of reproducing under each species the references to the literature given by Dr. A. S. Woodward in his Catalogue of the Fossil Fishes in the British Museum, supplementing the same in some cases by citations from more recent papers.

SYSTEMATIC CATALOG.

Elasmobranchii.

Considering the abundance and excellent state of preservation of fossil fishes in the Upper Eocene limestone of Monte Bolca, the relative paucity and lack of variety displayed by cartilaginous forms— sharks and rays— are surprising features. Detached hard parts, such as teeth, dermal fin-spines, and shagreen scales are extremely infrequent, and complete skeletons of *Lamnidæ* and other sharks probably are not represented in the museums of the world by more than a dozen specimens. On the other hand, rays are represented by a large number of species and individuals. Of these the commoner form, and at the same time the most exquisitely preserved, is the sting-ray first described by Volta as *Raja muricata* and renamed *Trygon gazzolæ* by Agassiz. The Carnegie Museum is fortunate in having an excellent example of this species, as noted below, and also an admirable cast of *Carcharias* (*Scoliodon*) *cuvieri* taken from perhaps the most perfect example yet discovered, the original of which is preserved in Bologna.

The following is a list of all Elasmobranch species at present known to occur in the Eocene fauna of Monte Bolca:

1. *Rhinobatus zignii* (Heckel).
2. *Rhinobatus primævus* Zigno.
3. *Platyrhina bolcensis* (Heckel).
4. *Platyrhina egertoni* Zigno.
5. *Platyrhina gigantea* (Blainville).
6. *Narcine molini* Jaekel.
7. *Trygon muricatus* (Volta).
8. *Trygon zignii* (Molin).

9. *Urolophus crassicaudatus* (Blainville).
10. *Promyliobatis gazolæ* (Zigno).
11. *Lamna vincenti* Winkler.
12. *Odontaspis hopei* Agassiz.
13. *Carcharodon auriculatus* Agassiz.
14. *Pseudogaleus voltai* Jaekel.
15. *Alopiopsis plejodon* Lioy.
16. *Carcharias* (*Scoliodon*) *cuvieri* (Agassiz).
17. *Mesiteia emiliæ* Kramberger.

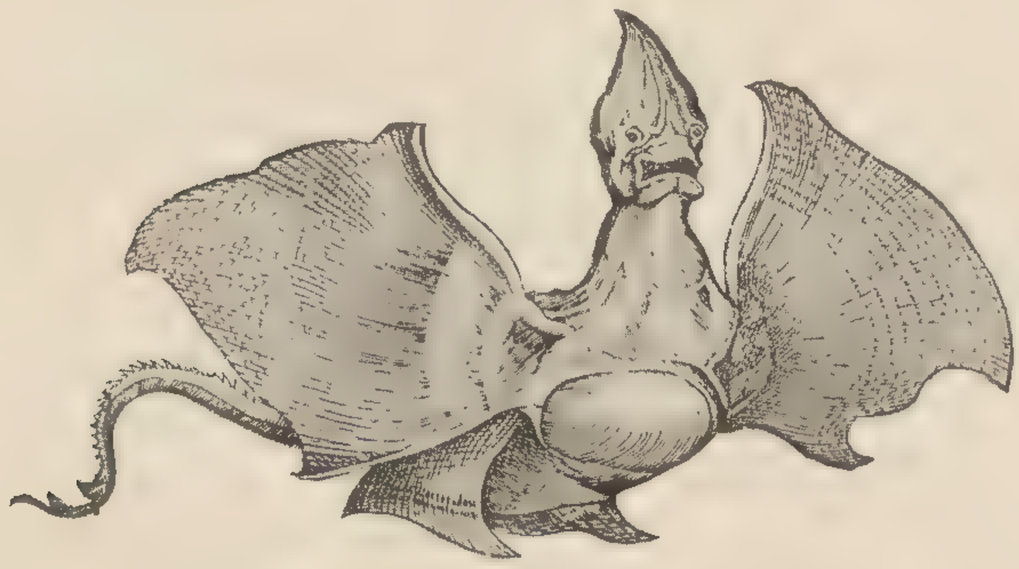

FIG. 1. Figure of a "Sting-ray" prepared and mounted to represent the form of a dragon, as was done by the Italian fishermen in the seventeenth century. Reproduced from the works of Ulysses Aldrovandi, Vol. IV (*De Piscibus*), p. 443. Bologna, 1638.

Family TRYGONIDÆ.

1. **Trygon muricata** (Volta).*

1796. *Raja muricata*, G. S. Volta, Ittiolit. Veronese, p. 37, pl. IX, figs. 1, 2.
1818. *Trygonobatus vulgaris*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 336.
1835. *Trygon gazzolæ*, L. Agassiz, Neues Jahrb., p. 297.
1843. *Trygon gazzolæ*, L. Agassiz, Poiss. Foss., Vol. III, p. 382**.
1861. *Alexandrinum*, R. Molin, Sitzungsb. k. k. Akad., Wiss. Wien, Vol. XLII, p. 579.
1874. *Alexandrinum molinii*, A. de Zigno, Mem. R. Istit. Veneto, Vol. XVIII, p. 299, pl. XII.
1874. *Alexandrinum molinii*, A. de Zigno, Catalogo Ragionato dei Pesci Fossili, p 181.
1874. *Trygon gazo'æ*, A. de Zigno, *op. cit.*, p. 180.

*The Editor has taken the liberty of substituting the feminine form, *muricata*, for the masculine, as the noun *Trygon* is feminine. W. J. H.

1894. *Trygon (Tæniura) muricatus*, O. Jaekel, Die Eocänen Selachier vom Monte Bo'ca, p. 142, pl. IV, fig. 32.

1904. *Trygon muricatus*, C. R. Eastman, Bull. Mus. Comp. Zoöl., Vol. XLVI, p. 23.

1905. *Trygon muricatus*, C. R. Eastman, Mém. Soc. Géol. de France, Vol. XIII, No. 34, p. 8.

The above synonymy is based upon a comparative study of the type specimen and other Eocene rays in the Gazzola Collection, which forms one of the ornaments of the Paris Museum of Natural History. The chief stumbling block which has stood in the way of the recognition and proper characterization of this species has called forth the following remarks from Dr. Otto Jaekel ("*Die Eocänen Selachier vom Monte Bolca*," 1894): "Es ist auffallend, dass eine Form, die bereits von Volta vortrefflich beschrieben und abgebildet war, und welche durch ihren reich gegliederten Skeletbau so leicht kenntlich ist, so viele nachträgliche Benennungen erfahren hat. Volta kannte und beschrieb das hier, Tafel IV, abgebildete Exemplar der Collection Gazola; allerdings rechnete er zu der gleichen Art, die er als *Raja muricata* bezeichnete, noch ein mit einem Stachel besetztes Schwanzfragment (*l. c.*, Taf. IX, Fig. 2), welches zu *Urolophus crassicauda* [*sic*] gehört. . . . Zu den späteren Benennungen gab z. Th. die Auffindung neuer Exemplare und die Nichtberücksichtigung des vorher beschriebenen Veranlassung" (p. 142).

This species is represented by a single perfect example, preserved in counterpart (Cat. No. 4521, 4521*a*) in the Bayet Collection of the Carnegie Museum. It is of rather small size, a little less than 40 cm. in total length, and probably represents an immature individual. The entire anatomy is beautifully displayed, and the caudal spine, which is preserved *in situ*, is of the same configuration as the original of Volta, *op. cit.*, Pl. IX, fig. 2.

CARCHARIIDÆ.

2. **Carcharias (Scoliodon) cuvieri** (Agassiz).

1796. *Squalus carcharias*, G. S. Volta, Ittiolit. Veronese, p. 10, pl. III, fig. 1.

1818. *Carcharias innominatus*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 336 (*errore*).

1839. *Galeus cuvieri*, L. Agassiz, Poiss. Foss., Vol. IV, p. 33 (name only).

1860. *Protogaleus cuvieri*, R. Molin, Sitzungsber. k. k. Akad., Wiss. Wien, Vol. XL, p. 583.

1874. *Alopiopsis cuvieri* (*pars*), A. de de Zigno, Catalogo Ragionata dei Pesci Fossili, p. 174.

1889. *Protogaleus cuvieri*, A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. 1, p. 437.

1894. *Galeus cuvieri*, O. Jaekel, Die Eocänen Selachier vom Monte Bolca, p. 172, text fig. 38.

1904. *Carcharias* (*Scoliodon*) *cuvieri*, C. R. Eastman, Bull. Mus. Comp. Zoöl., Vol. XLVI, p. 25, text-figure *a*.

1905. *Carcharias* (*Scoliodon*) *cuvieri*, C. R. Eastman, Mém. Soc. Géol. France, Vol. XIII, No. 34, p. 9, text-figure 1.

The holotype of this species, described in the first instance by Volta, and within recent years by Dr. Otto Jaekel and the present writer, forms part of the Gazzola Collection in the Paris Museum of Natural History. Another specimen, slightly smaller than the type, is preserved in the Museum of the University of Padua, and a third, more complete than either of these two, belongs to the Capellini Museum at the University of Bologna. Exquisite reproductions of this and two other important specimens of fishes from Monte Bolca were presented to the Carnegie Museum in 1909 by Senator Giovanni Capellini.

Fortunately the Bolognese and Parisian specimens supplement each other in several noteworthy respects, for instance as regards the form and position of the

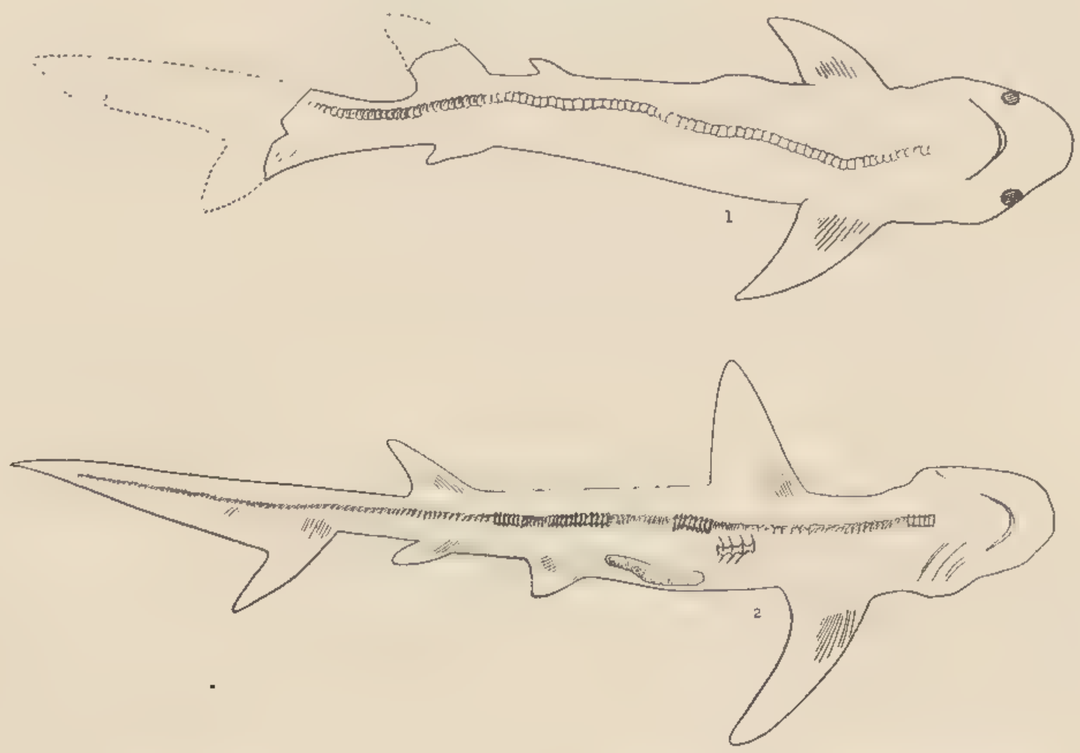

FIG. 2. (1) *Carcharias* (*Scoliodon*) *cuvieri* Agassiz. Outline figure of the holotype preserved in the Paris Museum of Natural History. ×1/9. (2) *Carcharias* (*Scoliodon*) *cuvieri* Agassiz. Outline figure of the Bolognese example, drawn from the replica in the Carnegie Museum (Cat. No. 4547). ×1/9.

median fins, nature of the shagreen covering, dentition, etc. The anterior dorsal is not shown in the Bolognese example, but as an offset to this the pelvic pair is

well displayed. Both specimens show undigested food and coprolitic matter within the intestinal tract, the course of which latter is clearly indicated.

The accompanying text-figures will show the general configuration of body in the species under consideration, as exemplified by the two individuals just mentioned.

TELEOSTOMI.

Suborder *PROTOSPONDYLI.*

Family PYCNODONTIDÆ.

3. **Pycnodus platessus** Blainville.

1796. *Coryphena apoda*, G. S. Volta, Ittiolit. Veronese, p. 197, pl. XXXV, fig. 1.

1818. *Zeus platessus*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII.

1833–34. *Pycnodus platessus*, L. Agassiz, Poiss. Foss., Vol. II, pt. 1, p. 185, pl. LXXII, figs. 1, 2 (*non* figs. 3, 4).

1856. *Pycnodus platessus*, J. J. Heckel, Denkschr. k. k. Akad. Wiss. Wien, math.-naturw. Cl., Vol. XI, pp. 204, 226, pl. VIII, figs. 5, 7.

1895. *Pycnodus platessus*, A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. III, p. 276.

1905. *Pycnodus apodus*, C. R. Eastman, Mém Soc. Géol. France, Vol. XIII, No. 34, p. 10.

The type is a nearly complete fish contained in the Paris Museum of Natural History.

The specimens representing this species attain on the average a length of about 30 cm. Maximum depth of trunk equalling half the length of the fish exclusive of the caudal fin; head with opercular apparatus occupying about one-quarter of the total length. Teeth of the splenial bone smooth, the outermost indented; the inner or principal series equalling in breadth the two flanking series, of which the inner comprises teeth broader than long, the outer being composed of nearly round teeth. Dorsal fin occupying somewhat less than three-quarters of the total length of the back, arising almost at the highest point.

Of this rare species a single example is preserved in the British Museum; several, in addition to the type, are found in the Paris Museum of Natural History, and one tolerably complete example is preserved in the Carnegie Museum (Cat. No. 4479, 4479*a*).

4. **Pycnodus gibbus** Agassiz. (Plate XCV, fig. 3.)

1796. *Coryphæna apoda* var., G. S. Volta, Ittiolit. Veronese, p. 147, pl. XXXV, fig. 2.

1796. *Diodon reticulatus*, G. S. Volta, *ibid*, p. 94, pl. XX, fig. 3.

1844. *Pycnodus gibbus* = *Pycnodus platessus*, L. Agassiz, Poiss. Foss., Vol. II, pt. II, pl. 185, pl. LXXII, figs. 3, 4.

1856. *Pycnodus gibbosus*, J. J. Heckel, Denkschr. Akad k. k. Wiss., math.-naturw. Cl., Vol. XI, p. 226, pl. VIII, figs. 3, 4, 6.

1895. *Pycnodus gibbus*, A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. III, p. 276.

The type is a nearly complete fish, the location of which is unknown.

A small species, attaining a length of about 15 cm., maximum depth of trunk slightly exceeding half the total length of the fish (including the caudal fin); head with opercular apparatus occupying somewhat more than one-quarter of the total length. Teeth and fins apparently as in the type species.

Regarded by Agassiz in his final work as the young of *P. pla'essus*, its differential characters were pointed out by Heckel in 1856. Three examples of this form occur among the series of fossil fishes belonging to the Carnegie Museum. They are cataloged under the following numbers: 4480+4480*a*; 4481; 4482.

Suborder *ISOSPONDYLI*.

Family Clupeidæ.

Genus Clupea (Artedi) Linné.

Three well recognized species of this genus are known from the Upper Eocene of Monte Bolca, and eight others have been named, without, however, having been scientifically defined or illustrated. In addition, at least two generic titles have been proposed for Clupeoid forms from Monte Bolca, the precise status of which is uncertain.[2] Not improbably some of the smaller types upon which separate species have been founded are to be regarded as the fry of well known larger Clupeoids. In this connection it may be pertinent to quote the following extract from Dr. A. S. Woodward's Catalogue of Fossil Fishes (Part IV, p. 158):

"The following names are also ascribed to supposed Clupeoids from the Upper Eocene of Monte Bolca by P. Lioy (Atti Soc. Ital. Sci. Nat., Vol. viii, 1865, pp. 411–414), but neither the genera nor species are scientifically defined or recognizable: *Clupea ophthalmica, C. chrysosoma, C. microcephala, C. minutissima, C. cephalus, Uropterina platyrachis, Ptericephalina macrogastrina* and *P. elongata*."

The Clupeoids from Monte Bolca which are represented in the collections of

[2] For instance, an undefined species named *Clupea leptostea* by Agassiz (Neues Jahrbuch, 1835, p. 120) is regarded by P. Lioy as type of a distinct genus, *Ptericephalina*. No illustrations have been published by either of these authors or by subsequent writers of the species thus designated, hence the difficulty of determining whether or not it should rank as an independent genus or species.

the Carnegie Museum are mostly small forms, the greater number of which are referable to the species which was named by Agassiz *Clupea catopterygia*, but the description of which was first published in 1901 by Dr A. S. Woodward. Over a score of Clupeoid species from the same horizon and locality have been described since the time of Agassiz by various authors, many of them in publications not readily accessible; and as the present writer has not yet had an opportunity to consult the original descriptions, nor to study the actual types, except in a few cases, a precise determination of all the specimens in the Bayet Collection has not been attempted. It will suffice for the present to note that the genus *Clupea* is represented in the Carnegie Museum by specimens having the following catalog numbers:

Clupea: Cat. No. 4511 (in counterpart); 4202; 4203; 4204; 4205; 4206; 4219; 4223; 4011; 4012; 4315; 4505; 4506; 4507; 4508; 4509 (in counterpart); 4510.

Suborder *APODES*.

Family MURÆNIDÆ.

The extinct species of this family, which appear sparsely in the Upper Cretaceous, and become more abundant in the Eocene, are still imperfectly known. Several anguilliform *types inédits*, designated as such by Professor Louis Agassiz, have recently been described by the present writer from Bolca material preserved in the Paris Museum of Natural History. Some of the undermentioned specimens are remarkable for their fine state of preservation. The name *Leptocephalus* is retained as a convenient designation for the young of various eel-like species.

Genus EOMYRUS Storms.

5. **Eomyrus ventralis** (Agassiz).

1835. *Anguilla ventralis*, L. Agassiz, Neues Jahrb., p. 307 (name only).

1839–44. *Anguilla ventralis*, L. Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 15; pt. II, p. 134, pl. XLIII, figs. 2, 3.

1898. *Anguilla ventralis* (?=*Eomyrus*), R. Storms, Bull. Soc. Be'ge Géol., Vol. X, Mém., p. 240.

1901. *Eomyrus ventralis*, A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. IV, p. 341.

Type.—Nearly complete fish; location unknown; *olim* Hartmann Collection.

This is a rare form, not represented in the collections of the British Museum, and by but a single specimen in the Bayet Collection of the Carnegie Institute, which is cataloged as No. 4017. A specimen of *Clupea* is preserved on the same slab.

6. **Eomyrus latispinus** (Agassiz).

1835. *Anguilla latispina*, L. Agassiz, Neues Jahrb., p. 307 (name only).

1839–44. *Anguilla latispina*, L. Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 15; pt. II, p. 133, pl. XLIII, fig. 4.

1901. *Eomyrus latispinus*, A. S. Woodward, Cat. Foss. Fishes Brit. Mus., pt. IV, p. 340.

1905. *Eomyrus latispinus*, C. R. Eastman, Mém. Soc. Géol. France, Vol. XIII, No. 34, p. 15.

Type.—Nearly complete fish; Paris Museum of Natural History. The specimen cataloged as No. 4411 is the solitary example of this species represented in the Bayet Collection. Four specimens are preserved in the British Museum.

7. **Eomyrus formosissimus** Eastman. (Plate XC, fig. 1.)

1796. *Ophidium barbatum*, Volta, Ittiolit. Veronese, p. 157, pl. XXXVIII, fig. 2 (*errore*).

1835. *Sphagebranchus formosissimus*, L. Agassiz, Neues Jahrb., p. 307 (name only).

1844. *Sphagebranchus formosissimus*, L. Agassiz, Poiss. Foss., Vol. V, pt. II, p. 138 (name only).

1905. *Eomyrus formosissimus*, C. R. Eastman, Mém. Soc. Géol. France, Vol. XIII, No. 34, p. 15, pl. IV, fig. 1; pl. V, fig. 1.

Type.—Nearly complete fish; Paris Museum of Natural History.

A single nearly complete example of this species, preserved in counterpart, is included in the Bayet Collection, and compares favorably with the type specimen. It is cataloged as No. 5233+5233*a*, and one of the halves is shown on the accompanying plate.

LEPTOCEPHALUS.

Most of the following specimens agree closely with the so-called *Leptocephalus gracilis* of Agassiz, which is evidently immature: 4224; 4225; 4231; 4296; 4458; 4524; 4525; 4526; 4527; 4528 (faint impression). Nos. 4524 and 4526 are in counterpart.

Suborder *PERCESOCES*.

Elevated to the rank of a separate order, this group is stated by Mr. C. Tate Regan to be "defined by the presence of a spinous dorsal, the abdominal pelvic fins each formed of a spine and five branched rays, and the absence of peculiarities of related groups." The same author also remarks:[3] "The supposed relationship

[3] Notes on the Classification of Teleostean Fishes. Proc. Seventh Zool. Congress, Boston Meeting. Cambridge, 1910.

of the Scombresocidæ to the Atherinidæ is based on a number of resemblances which do not in my opinion indicate affinity. The Percesoces are more specialized than the Scombresocidæ in that spinous fin-rays are developed, and features in which the Atherinidæ approximate to the Scombresocidæ appear to have been evolved within the order Percesoces rather than to be those of the prototype of the group."

Family ATHERINIDÆ (Silversides).

Genus RHAMPHOGNATHUS Agassiz.

This genus, which is identical with *Mesogaster* Agassiz, is with difficulty distinguished from various existing Atherinine genera, such as *Chirostoma*, *Menidia*, and *Atherinoides*. The modern forms are mostly marine and of small size.

8. **Rhamphognathus paralepoides** Agassiz.

1796. *Esox sphyræna*, G. S. Volta, Ittiolit. Veronese, p. 107, pl. XXIV, fig 2 (*errore*).

1796. *Esox saurus*, G. S. Volta, *ibid.*, p. 206, pl. I, fig. 2 (*errore*).

1796. *Ammodytes tobianus*, G. S. Volta, *ibid.*, p. 220, pl. LIII, fig. 3 (*errore*).

1818. *Ammodytes tobianus*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 360.

1835. *Rhamphognathus paralepoides*, L. Agassiz, Neues Jahrb., p. 292 (name only).

1839–44. *Rhamphognathus paralepoides*, L. Agassiz, Poiss. Foss., Vol. V, pt. I, p. 104, pl. XXXVIII, fig. 1 (*R. pompilius* on plate).

1876. *Rhamphognathus paralepoides*, F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 186.

1898. *Rhamphognathus paralepoides*, F. Bassani, Palæont. Italica, Vol. III, p. 81, pl. IX, fig. 3.

Type.—Imperfect fish; Paris Museum of Natural History.

This species is not represented in the British Museum. One fine example in counterpart is preserved in the Bayet Collection, cataloged as No. 5241, 5241*a*. It has a total length of 19 cm. and has all the fins intact.

Family SPHYRÆNIDÆ (Barracudas).

Genus SPHYRÆNA (Artedi) Bloch and Schneider.

A figure of the skeleton of *Sphyræna* is given by Agassiz in Vol. 5, pl. F, of his *Poissons Fossiles*.

9. **Sphyræna bolcensis** Agassiz.

1796. *Esox sphyræna*, G. S. Volta, Ittiolit. Veronese, p. 107, pl. XXIV, fig. 1.

1796. *Perca punctata*, G. S. Volta, *ibid.*, p. 208, pl. LI, fig. 1 (*errore*).

1796. *Esox lucius*, G. S. Volta, *ibid.*, p. 253, pl. LXII (*errore*).
1818. *Esox spret*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 341 (*errore*).
1835. *Sphyræna bolcensis*, L. Agassiz, Neues Jahrb., pp. 292, 294, 305.
1835. *Sphyræna gracilis* and *maxima*, L. Agassiz, *ibid.*, p. 305.
1843–44. *Sphyræna bolcensis*, L. Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 95, pl. X, fig. 2.
1843–44. *Sphyræna gracilis*, L. Agassiz, *ibid.*, p. 96, pl. X, fig. 1.
1844. *Sphyræna maxima*, L. Agassiz, *ibid.*, p. 97 (name only).
1876. *Sphyræna bolcensis*, F. Bassani, Atti. Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 185.
1891. *Sphyræna bolcensis*, A. S. Woodward, Brit. Mus. Cat. Foss. Fishes.

Type.—Imperfect fish; Paleontological Museum, Munich.

Six examples of this species are preserved in the British Museum, four in the Bayet Collection of the Carnegie Museum, one of which is in counterpart. These are cataloged as Nos. 4007, 4314, 4357, and 4357*a*, 5240. In No. 4357 the vertebral column is displayed to advantage and seen to consist of twenty-one centra.

Suborder *THORACOSTEI*.

Under this head Swinnerton,[4] following Smith Woodward's suggestion, has proposed to unite the Lophobranchs of Cuvier with the Hemibranchs of Cope. As remarked by Boulenger in the volume on fishes in the Cambridge Natural History, "the structure of the Lophobranchs (Solenostomidæ and Lyngnathidæ) shows that these fishes are only extremely specialized forms of the group of which the Sticklebacks are the well known type, and the character of the 'tufted' gills alone is surely not of sufficiently great importance to warrant the retention of the Lophobranchii as a division equivalent to the suborders adopted in the present classification."

The diagnostic character of this group, which, according to Mr. Regan, may be related to the Scombresocidæ, is the presence of a large dermal plate on each side, which in the adult is coössified with the coracoid and anteriorly united by suture to the clavicle. There are two well-marked divisions, the *Gasteroidei* and *Aulostomatoidei*.

Family Fistulariidæ (Cornet Fishes).

Aulostoma, by some regarded as type of a distinct family, *Fistularia* ("Trumpet Fish" or "Flute-mouth" of recent faunas) and *Urosphen* are the only known repre-

[4] *Quart. Journ. Micr. Soc.*, 1902, Vol. XLV, p. 503.

sentatives of this family in the Bolca Eocene. Dr. A. S. Woodward gives the following tabulation of differential characters in these genera:

Synopsis of Genera.

No free dorsal spines; caudal fin forked, with elongated median rays; no scales *Fistularia.*
A series of free dorsal spines; caudal fin rhombic, without elongated ray; small ctenoid scales present..... *Aulostoma.*
Imperfectly known, but all caudal fin-rays much elongated; no scales..... *Urosphen.*

Of the above-mentioned genera, only one imperfect example of *Aulostoma* is preserved in the British Museum. The Carnegie Museum possesses two good examples of *Urosphen,* but none of *Aulostoma* or *Fistularia.* A figure of the existing *F. tabaccaria,* which sometimes attains a length of six feet, is given by Agassiz in his *Poissons Fossiles,* Vol. IV, pl. 35, fig. 1 (wrongly labelled *Aulostoma chinensis*).

Genus Urosphen Agassiz.

10. **Urosphen dubia** (Blainville). (Plate XC, fig. 2; Plate XCVI, fig. 2.)

1796. *Fistularia tabacaria,* G. S. Volta, Ittiolit. Veronese, p. 130, pl. XXIX, fig. 4 (*errore*).
1818. *Fistularia dubia,* Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 341.
1839–42. *Urosphen fistularis,* L. Agassiz, Poiss. Foss., Vol. IV, p. 284, pl. XXXV, fig. 6 (name only).
1874. *Urosphen fistularis,* A. de Zigno, Catalogo Ragionato dei Pesci Fossili, p. 107.
1876. *Urosphen fistularis,* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 182.
1905. *Urosphen dubia,* C. R. Eastman, Mém. Soc. Géol. de France, Vol. XIII, No. 34, p. 20.

Type.—Imperfect fish; Paris Museum of Natural History.

This, the type species, attains a length of about 45 cm., of which the elongated caudal fin forms one-fourth. The dorsal and anal fins are similar and opposite, and in the smaller of the two under-mentioned specimens eighteen rays are to be counted in each.

4015, 4015*a*. Imperfect specimen, in counterpart, in which the head has a length of 13 cm., and the trunk is preserved to a point a little behind the median fins. Illustrated in Plate XC, fig. 2.

4499. Small, excellently preserved example, in which the unpaired fins are well displayed. Shown in Plate XCVI, fig. 2.

Suborder *SOLENICHTHYES.*

This group is apparently related to the preceding (Thoracostei), but differs from it in that on each side a series of plates takes the place of the single dermal plate of the latter. There are two families, the *Centriscidæ* and *Amphisilidæ.*

Family Centriscidæ.

Centriscus, with five species in the Atlantic and Pacific Oceans, represents the family at the present day. Isolated spines from the Pliocene of Tuscany have been referred to the same genus. *Rhamphosus,* from the Upper Eocene of Monte Bolca, is believed to have been allied to *Centriscus.*

Genus Rhamphosus Agassiz.

11. **Rhamphosus aculeatus** (Blainville).

1796. *Uranoscopus rastrum,* G. S. Volta, Ittiolit. Veronese, p. 22, pl. V, fig. 4.
1796. *Centriscus,* G. S. Volta, *ibid.,* pl. LXXV, fig. 1 (*errore*).
1818. *Centriscus aculeatus,* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVIII, p. 339.
1835. *Rhamphosus aculeatus,* L. Agassiz, Neues Jahrb., p. 291 (name only).
1839–42. *Rhamphosus aculeatus,* L. Agassiz, Poiss. Foss., Vol. IV, p. 270, pl. XXII, fig. 7.
1888. *Rhamphosus aculeatus,* L. Vaillant, Expéd. Scient. Travailleur et Talisman—Poissons, p. 339.
1898. *Rhamphosus aculeatus,* F. Bassani, Palæontogr. Italica, Vol. III, p. 82, pl. IX, fig. 4.
1901. *Rhamphosus aculeatus,* A. S. Woodward, Cat. Fossil Fishes Brit. Mus., Part IV, p. 377.

Type.—Imperfect fish, Paris Museum of Natural History.

This species is represented in the British Museum collections by a single imperfect specimen, and in the Carnegie Museum by a complete head, including the attenuated and elongated snout, of a rather small-sized example. (Cat. No. 4213.)

Suborder *ACANTHOPTERYGII.*

This large and well characterized suborder, the most comprehensive of the whole class of Pisces, is commonly understood as embracing the *Berycidæ* and allied families, together with the *Perciformes, Scombriformes, Kurtiformes, Jugulares, Gobiiformes,* etc., of Boulenger. The removal of the berycoid fishes to form

separate assemblages has recently been proposed by Mr. Regan,[5] whose reasons for this procedure are thus stated:

"It is usually recognized that the berycoid fishes are very generalized, as is shown by the large number of rays in the pelvic fins, the persistence of the pneumatic duct in certain genera, and the abundance of the group in Cretaceous times. . . . In the Holocentridæ and Berycidæ the attachment [of the pelvic bones to the clavicles] is by ligament, and in the Polymixiidæ the pelvic bones are quite remote from the clavicles; in the last-named the outermost ray of the pelvic fin, although simple, is not spinous, but articulated. In many species of *Myripristis* the distal part of the maxillary enters the gape when the mouth is widely opened and bears a series of true teeth which are set in sockets. . . . These facts lead me to believe that the resemblance of the Cretaceous Clupeoids, *Ctenothrissa* and *Pseudoberyx*, to the berycoids may be due to their real affinity, and that they may have belonged to the group from which the berycoid fishes have evolved."

Division A. BERYCIFORMES.

(Order *Berycomorphi* Regan.)

In this division the pelvic fins are thoracic, usually with more than five articulated rays in addition to the spine. No bony stay between the circumorbital ring and preoperculum.

Family Berycidæ.

This family, in the language of Boulenger, "is remarkable for the retention of two archaic characters: the large number of rays in the ventral fins, and the duct between the air-bladder and the digestive tract; the latter character is, however, not universal, and has only been found in two genera (*Beryx* and *Holocentrum*). The scaling of the body varies greatly, and so does the development of the spines in the vertical fins."

The *Berycidæ* were abundantly represented in Cretaceous times by *Beryx* and other genera more or less closely related to living forms, and they appear to have been the precursors of the Perciform fishes. About seventy species, referred to thirteen genera, are known to live at the present day, mostly at great depths, in the seas nearly all over the world.

Genus Myripristis Cuvier.

A figure of the skull of this genus, and one of the skeleton of *Holocentrum*, are given by Agassiz in Vol. IV, plate B, of his *Poissons Fossiles*.

[5] Advance Print from Proc. Seventh International Zool. Congress, Boston Meeting, 1910, p. 12.

12. **Myripristis leptacantha*** Agassiz.

1796. *Perca formosa*, G. S. Volta, Ittiolit. Veronese, p. LXXX, pl. XVII, fig. 2 (*errore*).

1818. "*Perca formosa*," H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 347.

1838–39. *Myripristis leptacanthus*, L. Agassiz, Poiss. Foss., Vol. IV, pp. 5, 111, pl. XV, fig. 4.

1876. *Myripristis leptacanthus*, F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 176.

1901. *Myripristis leptacanthus*, A. S. Woodward, Brit. Mus. Cat. Foss. Fishes, Pt. IV, p. 410.

Type.—Imperfect fish; Paleontological Museum, Munich.

This species is represented in the collection of the Carnegie Museum by a number of well preserved examples, cataloged as follows: 4209, 4216, 4338, 4435, 4446, 4495, 4496, 4497.

Genus Holocentrum (Artedi) Cuvier.

13. **Holocentrum macrocephalum** Blainville. (Pl. XCII, fig. 1.)

1796. *Holocentrus sogo*, G. S. Volta, Ittiolit. Veronese, p. 210, pl. LI, fig. 2 (*errore*).

1796. *Chætodon saxatilis*, G. S. Volta, *ibid.*, p. 265, pl. LXIV, fig. 1 (*errore*).

1796. *Chætodon*, G. S. Volta, *ibid.*, pl. LXXII, fig. 1 (*errore*).

1818. *Holocentrus macrocephalus*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 349.

1818. *Chætodon saxatilis*, H. D. de Blainville, *ibid.*, p. 353 (*errore*).

1834–36. *Holocentrum pygæum* L. Agassiz, Poiss. Foss., Vol. IV, pp. 6, 107, pl. XIV.

1901. *Holocentrum macrocephalum*, A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, Part IV, p. 413.

Type.—Imperfect fish; Paris Museum of Natural History.

Several fine large specimens, as perfect as any hitherto reported, besides a number of smaller ones, form part of the Bayet Collection in the Carnegie Museum. A typical example is represented in Plate XCII, fig. 1. The series is cataloged under the following numbers: 4368, 4370, 4372, 4437, 4444, 4445, 4455, 4494, 4495, 4502. The original of Plate XCII, fig. 1, is cataloged as No. 4455.

Division B. SCOMBRIFORMES.

As remarked by Boulenger, the series of families that cluster round the mackerel offer so many modifications of structure that it is impossible to draw up a diagnosis

*The noun *Myripristis* being feminine, the specific name should agree with it. *Editor.*

differentiating every one of its members from the *Perciformes*, with which they are closely connected, and from which they hardly deserve to be separated. The geological range of this division is from the Lower Eocene to the present day.

Family CARANGIDÆ (Pompanos, etc.).

Genus SEMIOPHORUS Agassiz.

14. **Semiophorus velifer** (Volta). (Plate XCVI, fig. 1.)

1796. *Kurtus velifer*, G. S. Volta, Ittiolit. Veronese, p. XXVII, pl. VII, figs. 1, 2 (*non* fig. 3).

1818. *Chætodon velifer*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 355.

1835. *Semiophorus velifer*, L. Agassiz, Neues Jahrb., p. 301 (name only).

1838–42. *Semiophorus velifer*, L. Agassiz, Poiss. Foss., Vol. IV, pp. 14, 219, pl. XXXVIIa.

1859. *Semiophorus velifer*, A. G. Massalongo, Specimen Photogr. Anim. Foss. Agr. Veron., p. 27, pl. VI.

1876. *Semiophorus velifer*, F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 179.

(?) 1878. *Semiophorus gigas*, A. de Zigno, Mem. R. Instit. Veneto, Vol. XX, p. 488, pl. XV.

1901. *Semiophorus velifer* (Volta), Brit. Mus. Cat. Fossil Fishes, Part IV, p. 430.

Type.—Nearly complete fish; Paris Museum of Natural History.

One fine specimen and two imperfect ones, partially restored, are preserved in the British Museum of Natural History. Two excellent examples, one of them a hypotype, having been figured by Massalongo, are contained in the Bayet Collection of the Carnegie Museum. An illustration is given of the original of Massalongo's figure in the accompanying plate. This bears the catalog No. 4467, and the second specimen that of No. 4466.

Genus PLATAX Cuvier.

15. **Platax subvespertilio** (Blainville).

This large and handsome species is not represented in the British Museum. The type and several other specimens are preserved in the Paris Museum of Natural History, others at Verona and elsewhere in Italy. A cast of an extraordinarily perfect example belonging to the University of Bologna (*olim* Zigno Coll.) was presented to the Carnegie Museum a few years ago through Senator G. Cappellini,

together with casts of *Carcharias* (=*Scoliodon*) and *Seriola*. This bears the catalog number of 4549.

Genus Vomeropsis Heckel.

16. **Vomeropsis longispinus** (Agassiz). (Plate XCIII, figs. 1, 2.)

1796. *Zeus vomer*, G. S. Volta, Ittiolit. Veronese, pl. XXXV, fig. 3 (*errore*).
1796. *Zeus triurus*, G. S. Volta, *ibid.*, p. 181, pl. XLIV, fig. 2 (*errore*).
1836–44. *Vomer longispinus*, L. Agassiz, Poiss. Foss., Vol. V, Pt. I, pp. 4, 28, pls. V, VI.
1854. *Vomeropsis longispinus*, J. J. Heckel, Sitzungsb. Akad. Wiss., math.-naturw. Cl., Vol. XI, p. 135.
1901. *Vomeropsis longispinus*, A. S. Woodward, Brit. Mus. Cat. Foss. Fishes, pt. IV, p. 436.

Type.—Imperfect, partly distorted fish; Paris Museum of Natural History.

One fine small specimen, and a larger imperfect one, are preserved in the British Museum. Two large, nearly complete examples belong to the Carnegie Museum, and are cataloged as numbers 4350 and 4489. These are shown of the natural size in the plate.

Genus Mene Lacépède.

This genus, represented in the existing fauna by a single East Indian species, and by two in the Eocene of Monte Bolca, has recently been studied in considerable detail by Dr. Rudolf Cramer (Zeitschr. deutsch. geol. Gesell., Jahrgang 1906, Band 58, pp. 181–212.) The accompanying diagram of the cranial osteology is reproduced from a figure given by this author.

17. **Mene rhombea*** (Volta). (Text-figure 3.)

1796. *Scomber rhombeus* G. S. Volta, Ittiolit. Veronese, p. 184, pl. XVIII.
1818. *Zeus rhombeus* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 356.
1833. *Gasteronemus rhombeus* L. Agassiz, Poiss. Foss., Vol. V, pt. I, p. 20, pl. II.
1901. *Mene rhombeus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 439.
1906. *Mene rhombeus* Rudolf Cramer, Zeitschr. deutsch. geol. Ges., vol. 58, p. 181, pl. X.

Type.—Nearly complete fish; Paleontological Museum, Munich.

Numerous fine examples of this species are preserved in the Carnegie Museum, the whole forming an excellent series for study. They are cataloged under the following numbers: 4009, 4010, 4344, 4349 (+4349*a*), 4353, 4365, 4310, 4369

* Μήνη *nom. fem.* ∴ rhombea. *Editor.*

(+4369*a*), 4483, 4484, 4485, 4486, 4487, 4488 (+4488*a*), 4493, 4490, 4491, 5235, 5236.

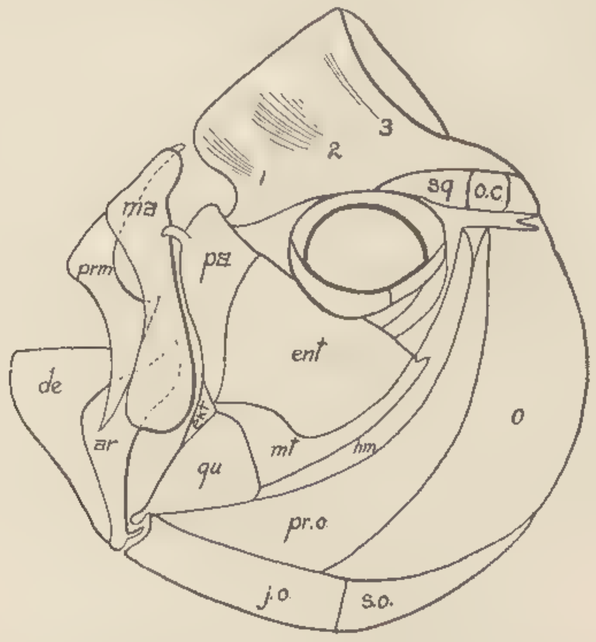

FIG. 3. *Mene rhombea* Volta. Restoration of head portion, showing cranial osteology, about one-half natural size (after Cramer). *ar*, articular; *de*, dentary; *ect*, ectopterygoid; *ent*, entopterygoid; *hm*, hyomandibular; *j.o.*, interoperculum; *ma*, maxilla; *mt*, metapterygoid; *o*, operculum; *pa*, palatine; *prm*, premaxilla; *pr.o*, preoperculum; *qu*, quadrate; *s.o.*, suboperculum; *sq*, squamosal; 1, 2, 3, the three centers of ossification visible in the cranial roof.

18. **Mene oblonga*** (Agassiz). (Plate XCII, fig. 3.)

This species is much rarer than the one immediately preceding. Two examples of it are reported as belonging to the British Museum, and four are now the property of the Carnegie Museum. These are catalogued as follows: 4333, 4337, 4492, 4020. The last mentioned specimen is shown of the natural size in Plate XCII, fig. 3.

Genus SERIOLA Cuvier.

Differs from *Caranx* in having the pectoral fins relatively small, anal shorter than the posterior dorsal, and no enlarged or thickened scales along the lateral line.

19. **Seriola prisca** (Agassiz). (Plates XCVII, fig. 6; XCVIII, fig. 1; XCIX, fig. 3; CI, fig. 2.)

1796. *Scomber pelagicus* G. S. Volta, Ittiolit. Veronese, p. 74, pl. XVI(*errore*).
1796. *Coryphæna* G. S. Volta, *ibid.*, pl. LXVIII (*errore*).
1818. *Scomber pelagicus?* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 346.
1835. *Lichia prisca* L. Agassiz, Neues Jahrb., p. 292 (name only).
1834–44. *Lichia prisca* L. Agassiz, Poiss. Foss., Vol. V, pt. I, p. 34, pls. XI, XI*a*.
1854. *Seriola prisca* J. J. Heckel, Sitzungsb. k. Akad. Wiss., math.-naturw. Cl., Vol. XI, p. 136.

*See editorial note at foot of p. 166.

1876. *Lichia prisca* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 184.
1901. *Seriola prisca* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 444.

Type.—Nearly complete fish; Paleontological Museum, Munich.

Numerous fine large specimens of this species are contained in the Bayet Collection of the Carnegie Museum, some of them exquisitely preserved, a few somewhat distorted. A replica of an unusually large individual, *olim* collection Baron de Zigno, now in the Capellini Museum of the University of Bologna, was presented to the Museum in 1909 through the courtesy of Senator Giovanni Capellini. It has a total length to base of the caudal fin of 25 inches (=62.5 cm.) and is cataloged as number 4548. The remaining examples bear the following departmental numbers: 4230 (*juv.*), 4545, 4006, 4018, 4295, 4364+4364*a*, 4373, 4413, 4469, 4410.

20. **Seriola analis** (Agassiz).

1796. *Scomber* G. S. Volta, Ittiolit. Veronese, pl. LXIX, fig. 1 (*errore*).
1796. *Polynemus* G. S. Volta, *ibid.*, pl. LXXV, fig. 3 (*errore*).
1835. *Carangopsis analis* L. Agassiz, Neues Jahrb., p. 304 (name only).
1843–44. *Carangopsis analis* L. Agassiz, Poiss. Foss., Vol. V, pt. I, p. 42, pl. IX, fig. 1.
1848. *Lichia analis* C. G. Giebel, Fauna d. Vorwelt, Fische, p. 76.
1901. *Seriola analis* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes pt. IV, p. 445.

Type.—Imperfect fish; Paleontological Museum, Munich.

This is a comparatively small and slender species, much rarer than the preceding. The anal fin is slightly longer than in the type, apparently with twenty-two articulated rays. Three examples are preserved in the British, and a like number in the Carnegie Museum, the latter cataloged as follows: 4003 (in counterpart); 4330, 4351 (also in counterpart).

Genus Carangopsis Agassiz.

This genus differs from *Caranx* in having larger teeth, no enlarged or thickened scales along the lateral line, and fin shorter than the posterior dorsal, and anal finspines insignificant, not separate from the fin.

21. **Carangopsis brevis** (Blainville).

1796. *Polynemus quinquarius* G. S. Volta, Ittiolit. Veronese, p. 153, pl. XXXVI (*errore*).
1818. *Mugil brevis* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 344.

1835. *Carangopsis latior* L. Agassiz, Neues Jahrb., p. 293 (name only).

1843–44. *Carangopsis latior* L. Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 40, pl. IX, fig. 2.

1876. *Carangopsis latior* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 185.

1901. *Carangopsis brevis* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 446.

Type.—Imperfect distorted fish; Paris Museum of Natural History.

This species is represented by a single example in the Bayet Collection, cataloged as No. 4371. It is very well preserved, and bears an original label which reads "*Carangopsis latior*," hand-writing unknown.

22. **Carangopsis dorsalis** Agassiz. (Plate XCI, fig. 2.)

1796. *Sciena undecimalis* G. S. Volta, Ittiolit. Veronese, p. 217, pl. LIII, fig. 1 (*errore*).

1818. *Sciæna undecimalis*? H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 348.

1835. *Carangopsis dorsalis* L. Agassiz, Neues Jahrb., p. 304 (name only).

1834–44. *Carangopsis dorsalis* L. Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 41, pl. VIII.

1901. *Carangopsis dorsalis* A. S. Woodward, Cat. Fossil Fishes British Museum, pt. IV, p. 447.

Type.—Imperfect fish; Paris Museum of Natural History.

Trunk somewhat less deep than in the type species, and anal fin with fourteen or fifteen articulated rays.

Six good specimens of this form are contained in the Bayet Collection of the Carnegie Museum, one of which, superior in point of preservation, is shown in the accompanying plate. The series is cataloged as follows: 4361, 4359, 4359*a*, 4345, 4530, 4530*a*, 4531, 4531*a*, 4537, 4537*a*.

Genus Ductor Agassiz.

23. **Ductor leptosomus** Agassiz.

1796. *Callionymus vestenæ* G. S. Volta, Ittiolit. Veronese, p. 140, pl. XXXII, fig. 2 (*errore*).

1796. *Gobius smyrnensis* G. S. Volta, *ibid.*, p. 241, pl. LVIII, fig. 2 (*errore*).

1818. "*Callionymus vestenæ*" H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 359.

1818. "*Gobius smyrnensis*" H. D. de Blainville, *ibid.*, p. 358.

1834. *Ductor leptosomus* L. Agassiz, Verhandl. Ges. Vaterland. Mus. Böhmen, p. 66 (name only).
1835. *Ductor leptosomus* L. Agassiz, Neues Jahrb., p. 293 (name only).
1834–44. *Ductor leptosomus* L. Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 53, pl. XII.
1876. *Ductor leptosomus* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 184.
1901. *Ductor leptosomus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 448.

Type.—Imperfect fish; Paris Museum of Natural History.

One large and several smaller and imperfect specimens are to be seen in the British Museum. The Carnegie Museum possesses a series catalogued as follows: 4214, 4220 and 4220*a*, 4227 (imperfect), 4130, 4513, 4514, 5242, 5243 (*juv.*).

Genus Acanthonemus Agassiz.

This genus, like the preceding, is entirely extinct, and known by a single species from the Upper Eocene and Upper Oligocene respectively, both exceedingly rare.

24. **Acanthonemus subaureus** (Blainville). (Plate XCIV.)

1796. *Zeus gallus* G. S. Volta, Ittiolit. Veronese, p. 87, pl. XIX, fig. 3 (*errore*).
1796. *Chætodon aureus* G. S. Volta, *ibid.*, p. 212, pl. LI, fig. 3 (*errore*).
1818. *Chætodon subaureus*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 354.
1834. *Acanthonemus filamentosus* L. Agassiz, Poiss. Foss., Vol. V, pt. I, p. 25, pls. III, IV.

Type.—Imperfect fish; Paris Museum of Natural History.

The fine example shown in the accompanying plate, cataloged as No. 4439, is the third example known. The other two, one of which is the type, belong to the Paris Museum. The six anterior dorsal fin-rays are greatly elongated.

Genus Trachynotus Lacépède.

To this genus, as re-defined by Cuvier from his study of recent forms, a single small species was somewhat doubtfully referred by Agassiz on the basis of a solitary example from the Eocene of Monte Bolca. After quoting Cuvier's remarks on the near approach of this genus to *Lichia* and its allies, Agassiz remarks: "D'après cela, on comprend qu'il doit être plus difficile encore de déterminer les espèces fossiles; surtout si toutes les parties du squelette ne sont pas parfaitement con-

servées. Aussi en rapportant à ce genre l'empreinte fossile que je vais décrire, je me suis laissé guider uniquement par la forme générale du poisson."

Further on, in his description of the holotype of *T. tenuiceps*, the same author observes: "Quoique on ne voit pas la dentition de l'intérior de la guele, la forme générale du poisson, les proportions du corps, et cet air de famille si inappréciable en histoire naturelle, compensent ce qu'il y a de défectueux dans les détails, et comme on ne peut balancer qu'entre les genres *Platax* et *Trachinotus*, il ne peut rester aucun doute sur sa position générique dans la famille des Scomberoides."

The above paragraphs are of interest as revealing the mental process, or personal equation on the part of an experienced student of ichthyology, who depended upon instinct, as it were—that is, an acquired second sight or delicacy of perception, or in a word *feeling*—in determining the systematic position of doubtful or of imperfectly preserved fossil remains. Be that as it may, no one has shown cause for removing Agassiz's so-called *Trachynotus tenuiceps* from the position assigned to it, and until the present time the type specimen has remained absolutely unique.

The Carnegie Museum is fortunate in possessing two well preserved examples which may be provisionally referred to the species described by Agassiz, although they greatly exceed the type in size, and one, which has a deeper form of body than Agassiz's original, may be found on further investigation to differ from it sufficiently to warrant the establishment of a separate species. The doubtful specimen last mentioned is illustrated in Plate C.

25. **Trachynotus tenuiceps** Agassiz. (Plate XCI, fig. 1.)

1796. *Chætodon rhomboides* (*errore*) G. S. Volta, Ittiolit. Veronese, p. 162, pl. XXXIX, fig. 3.

1835. *Trachinotus tenuiceps* L. Agassiz, Poiss. Foss., Vol. V, pt. I, p. 36, pl. VII.

Type.—Nearly perfect fish in counterpart; Paris Museum of Natural History.

Of the two examples provisionally referred to this species, the larger (Cat. No. 4367) is preserved on a single slab, the other in counterpart (Cat. No. 4532, 4532*a*). One of the containing slabs of the latter is shown in the accompanying plate. The individual which is not figured has a total length to base of the caudal fin of 16 cm.

Genus Zanclus.

Of this existing genus two fossil species have been described, one from the Eocene of Monte Bolca, the other from the Calcaire Grossier of Paris. No examples of either are found to be in the British Museum, and the undermentioned specimen of *Z. brevirostris* is the only one thus far reported besides the type. A figure of the recent *Z. cornutus* is given by Agassiz, Poiss. Foss., Vol. IV, pl. G, fig. 1.

26. **Zanclus brevirostris** Agassiz. (Plate XCVII, fig. 3.)

1796. *Chætodon canescens* Volta, Ittiolit. Veronese, pl. XXVI, fig. 2 (*errore*).

1842. *Zanclus brevirostris* L. Agassiz, Poiss. Foss., Vol. IV, p. 236, pl. XXXVIII.

Type.—Nearly complete fish; Paris Museum of Natural History.

Represented by a single admirably preserved specimen in the Bayet Collection, cataloged as No. 4415, and bearing an original label which reads as follows: "Dono di Eugenio Sardagno, Venezia 18 Nr. 1888, *ex* Galleria Manfrin." It is shown of the natural size in Plate XCVII, Fig. 3.

Family Scombridæ. Mackerels.

All the existing members of this family are marine, and all known fossil representatives occur in marine deposits. The Tunny, or Horse Mackerel (*Thynnus thynnus* Linn.) is the Tuna or Leaping Tuna of southern California, and is the largest fish of the mackerel family, reaching a length of ten feet or more, and a weight of 1500 pounds. It also occurs in the fossil state in the Pleistocene (Forest Bed Series) of Norfolk, England.

Genus Thynnus Cuvier.

(Syn. *Orycynus* Cuvier.)

27. **Thynnus lanceolatus** (Agassiz).

1796. *Scomber alatunga* G. S. Volta, Ittiolit. Veronese, p. 123, pl. XXIX, fig. 1 fig. 1 (*errore*).

1796. *Salmo cyprinoides* G. S. Volta, *ibid.*, p. 214, pl. LII.

1818. *Clupea cyprinoides* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 343.

1818. *Scomber altalunga* H. D. de Blainville, *ibid.*, p. 345 (*errore*).

1835. *Orycynus lanceolatus* L. Agassiz, Neues Jahrb., p. 293.

1835–44. *Orycynus lanceolatus* L. Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 59, pl. XXIII.

1876. *Orycynus lanceolatus* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 183.

1889. *Thynnus lanceolatus* R. Storms, Bull. Soc. Belge Géol., Vol. III, Mém., p. 178.

1901. *Thynnus lanceolatus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 456.

Type.—Imperfect fish; Paris Museum of Natural History.

This comparatively small species is represented by a single imperfect fish 22

cm. in length, partly distorted, in the British Museum of Natural History, and by two larger specimens measuring in total length 33 and 38 cm. respectively, in the Carnegie Museum. These are cataloged under the numbers 4223+4223*a*, and 4890. There is also a distorted and imperfectly restored specimen cataloged as No. 4363, which may possibly be referred to this species.

28. **Thynnus latior** (Agassiz).

1796. *Scomber orycynus* Volta, Ittiolit. Veronese, p. 226, pl. LV, fig. 2 (*errore*).
1844. *Orycynus latior* Agassiz, Poiss. Foss., Vol. V, p. 60, pl. XXIV.

Type.—Imperfect fish; Paris Museum of Natural History.

The type specimen of this form has remained up to the present time unique. One nearly complete individual, preserved in counterpart, belongs to the Bayet Collection, and is cataloged as No. 4533, 4533*a*. All of the fins are beautifully displayed.

29. **Thynnus bolcensis** Agassiz.

1796. *Scomber thynnus* Volta, Ittiolit. Veronese, p. 119, pl. XXVII (*errore*).
1844. *Thynnus bolcensis* Agassiz, Poiss. Foss., Vol. V, pt. 1, p. 57 (undescribed).

Type.—Imperfect fish. Paris Museum of Natural History.

The type and, until recently, solitary known example of this species was wrongly identified with the existing Tunny by Volta, and afterwards recognized by Agassiz as belonging to a distinct species, for which he proposed the undefined name of *Thynnus bolcensis*. A fine large example measuring 95 cm. in total length, and displaying the essential features to good advantage, forms one of the ornaments of the Bayet Collection. It is on exhibition in the Hall of Fossil Vertebrates, and is catalogued as No. 5245. A more detailed account of this form is reserved for a subsequent paper.

Genus Auxis Cuvier.

This genus resembles *Scomber* proper in having the two dorsal fins well separated, but the caudal pedicle carries a lateral keel and the pectoral scales are enlarged. The following species is doubtfully referred to this genus by A. Smith Woodward.

30. **Auxis (?) propterygia** (Agassiz).

1796. *Scomber pelamis* G. S. Volta, Ittiolit. Veronese, p. 66, pl. XIV, fig. 2 (*errore*).
1796. *Scomber trachurus* G. S. Volta, *ibid.*, p. 125, pl. XXIX, fig. 2 (*errore*).
1796. *Ophicephalus striatus* G. S. Volta, *ibid.*, p. 193, pl. XLVIII, fig. 1 (*errore*).
1818. *Scomber pelamis* (?) H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 345.

1818. *Scomber trachurus* H. D. de Blainville, *ibid.*, p. 345.
1818. *Labrus bifasciatus* ("? one of the species of Scomber"), H. D. de Blainville, *ibid.*, p. 351.
1835. *Thynnus propterygius* L. Agassiz, Neues Jahrb., p. 292 (name only).
1835–44. *Thynnus propterygius* L. Agassiz, Poiss. Foss., Vol. V, Pt. 1, p. 55, pl. XXVII.
1876. *Thynnus propterygius* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 183.
1882. *Thynnus propterygius* (? = *Auxis*), D. G. Kramberger, Beitr. Paläont. Oesterr.-Ungarns, Vol. II, p. 118.
1901. *Auxis* (*?*) *propterygius* A. S. Woodward, Brit. Mus. Cat. Foss. Fishes, pt. IV, p. 464.

Type.—Imperfect fish; Paris Museum of Natural History.

Of this rare and imperfectly known species a single small example is preserved in the British Museum, and one measuring 15 cm. in total length in the Carnegie Museum (Cat. No. 4013, 4013*a*).

Division C. PERCIFORMES.

The principal characters of this large division are thus summarized by Dr. Boulenger: "Rays of the caudal fin not strongly forked at the base; hypural usually with a basal spine or knob-like process on each side, epipleural bones usually inserted on the parapophyses or on the ribs; dorsal fin usually with strong spines; caudal peduncle rarely much constricted." (*loc. cit.* p. 651.)

Family Percidæ.

For figures of skulls and notes on the osteology of recent *Percidæ* see G. A. Boulenger, "Catalogue of the Perciform Fishes in the British Museum."

Genus Lates Cuvier and Valenciennes.

The existing species of this genus are tropical fresh-water forms.

31. **Lates gracilis** Agassiz. (Plate XCIV, fig. 2.)

1796. *Holocentrus calcarifer* G. S. Volta, Ittiolit. Veronese, p. 82, pl. XVII, fig. 3 (*errore*).
1796. *Lutianus ephippium*, G. S. Volta, *ibid.*, p. 235, pl. LVI, fig. 4 (*errore*).
1833–34. *Lates gracilis* L. Agassiz, Poiss. Foss., Vol. IV, p. 25, pl. III.
1833–34. *Lates gibbus* L. Agassiz, *ibid.*, p. 27, pl. IV. (Distorted fish.)
1833–34. *Lates notœus* L. Agassiz, *ibid.*, p. 29, pl. V. (Imperfect distorted fish; Paleontological Museum, Munich.)

1876. *Lates gracilis* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 174.

1876. *Lates gibbus* F. Bassani, *ibid.*, p. 174.

1901. *Lates gracilis* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 502.

Type.—Well-preserved fish; Paris Museum of Natural History.

This species is represented in the Bayet Collection by a number of excellent examples. The complete series is cataloged as follows: 4348, 4352, 4465, 4501, 4515, 4516, 4517. Of these Nos. 4515 and 4501 are in counterpart. No. 4501 is figured on Plate XCIX, and is a young individual.

Genus CYCLOPOMA Agassiz.

An extinct genus scarcely distinguishable from *Lates*, but preoperculum without spine at angle, its serrations gradually increasing in size downwards, and the lowest and largest forwardly directed.

32. **Cyclopoma gigas** Agassiz.

1796. *Labrus turdus* G. S. Volta, Ittiolit. Veronese, p. 202, pl. XLIX (*errore*).

1796. *Scorpæna* G. S. Volta, *ibid.*, pl. LXXIV.

1833. *Cyclopoma gigas* L. Agassiz, Poiss. Foss., Vol. IV, p. 18, pl. II.

1901. *Cyclopoma gigas* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 504.

Type.—Imperfect fish; Paris Museum of Natural History.

Of this, the type species, which attains a length of half a meter, two examples are the property of the British Museum, and four belong to the Carnegie Museum. These are all very fine large specimens, cataloged under the following numbers: 4311 (from Monte Postale, Italy); 4358 (head in counterpart and peculiar in having *four* anal spines instead of three, the usual number), 4406 (very large, in counterpart), and 4405.

33. **Cyclopoma (?) micracanthum** (Agassiz). (Plate XCVII, fig. 4).

1796. *Holocentrus maculatus* G. S. Volta, Ittiolit. Veronese, p. 234, pl. LVI, fig. 3 (*errore*).

1796. *Amia indica* G. S. Volta, *ibid.*, p. 149, pl. XXXV, fig. 4 (*errore*).

1818. *Amia indica* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 347.

1835. *Smerdis micracanthus* L. Agassiz, Poiss. Foss., Vol. IV, p. 33, pl. VIII, figs. 1, 2.

1836. *Dules medius* L. Agassiz, *ibid.*, p. 93, pl. XIII, fig. 4. (Imperfect fish; Paleontological Museum, Munich.)

1901. *Cyclopoma (?) micracanthum* A. S. Woodward, Brit. Mus. Cat. Foss. Fishes, pt. IV, p. 504.

Type.—Imperfect fish; *olim* Hartmann Collection, Göttingen.

This small species, included by Agassiz under *Smerdis*, but transferred by A. Smith Woodward to *Cyclopoma* on account of its serrated preoperculum, is abundantly represented in the Upper Eocene of Monte Bolca. The Carnegie Museum possesses six good examples, cataloged as follows: 4210, 4211, 4221, 4226, 4228, 4519. No. 4228 is represented by fig. 4, Plate XCVII.

Under this caption may perhaps be included a small form, regarded by A. Smith Woodward as the young of *C. micracanthum*, but placed by Agassiz in a distinct species, *Smerdis pygmæus*. The specimen cataloged as No. 4212 is an example, and is illustrated in Plate XCVII, Fig. 5.

Genus LABRAX Cuvier and Valenciennes.

34. **Labrax schizurus** Agassiz.

1836. *Labrax schizurus* L. Agassiz, Poiss. Foss., Vol. IV, p. 89, pl. XIII, figs. 2, 3.

1901. *Labrax schizurus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 510.

Type.—Imperfect fish; Paris Museum of Natural History.

This is a slender species attaining a total length of about 15 cm. It is represented by several specimens in the British Museum, and by a single small example in the Bayet Collection, cataloged as No. 4222.

35. **Labrax lepidotus** Agassiz.

1836. *Labrax lepidotus* Agassiz, Poiss. Foss., Vol. IV, p. 85, pl. XIII, fig. 1.

Type.—Fragmentary fish; Paleontological Museum, Munich.

Of this rare form two examples are known besides the type. One is the property of the Paris Museum of Natural History, the other belongs to the Carnegie Museum (Cat. No. 4356).

Genus DULES.

36. **Dules temnopterus** Agassiz.

1796. *Sciena plumierii* G. S. Volta, Ittiolit. Veronese, p. 185, pl. XLV, fig. 2 (*errore*).

1836. *Dules temnopterus* L. Agassiz, Poiss. Foss., Vol. IV, p. 91, pl. 21.

1876. *Dules temnopterus* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. 3, p. 175.

Type.—Imperfect fish; Paris Museum of Natural History.

No examples of this species are present in the British Museum and but one in the Carnegie Institute. This is catalogued as No. 4297.

Genus ENOPLOSUS Agassiz.

37. **Enoplosus pygopterus** Agassiz.

1796. *Scomber ignobilis* G. S. Volta, Ittiolit. Veronese, pl. XIV, fig. 1 (*errore*).

1836–37. *Enoplosus pygopterus* L. Agassiz, Poiss. Foss., Vol. IV, p 62, pl. IX, fig. 1.

1876. *Enoplosus pygopterus* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 175.

Type.—Imperfect fish; Paris Museum of Natural History.

The type of this species has hitherto remained unique. A second interesting example is that belonging to the Bayet Collection of the Carnegie Museum, which is cataloged as No. 4218, 4218*a*.

Genus DENTEX.

Four species from the Upper Eocene of Monte Bolca have been referred by Agassiz to this interesting genus, the position of which is considered to be intermediate between the *Percidæ* and *Sparidæ*. None of these is represented in the collections of the British Museum, but examples of the undermentioned form are to be found in the Carnegie Institute.

38. **Dentex leptacanthus** Agassiz.

1839. *Dentex leptacanthus* Agassiz, Poiss. Foss., Vol. IV, p. 144, pl. XXVI.

Type.—Imperfect fish; Paris Museum of Natural History.

The following mentioned examples of this species are preserved in the Bayet Collection: 4309 (in counterpart), 4335, 4360.

Family SPARIDÆ. (Porgies, Sea-Breams.)

This family embraces some two hundred living species, distributed over the coasts of nearly the whole world. Some are herbivorous, but the majority are carnivorous. The group is abundantly represented in Eocene and Miocene deposits by remains of *Sargus, Sparus, Pagrus, Pagellus,* etc., and by the extinct genera *Ctenodentex, Sparnodus, and Trigonodon.*

Genus SPARNODUS Agassiz.

39. **Sparnodus vulgaris** (Blainville).

1796. *Sparus macrophthalmus* G. S. Volta, Ittiolit. Veronese, p. 247, pl. LX, fig. 2 (*errore*).

1796. *Cyprinus* G. S. Volta, *ibid.*, pl. LXXIII.
1796. *Sparus dentex* G. S. Volta, *ibid.*, p. 62, pl. XIII, fig. 1 (*errore*).
1796. *Sparus sargus* G. S. Volta, *ibid.*, p. 76, pl. XVII, fig. 1 (*errore*).
1796. *Sparus erythrinus* G. S. Volta, *ibid.*, p. 249, pl. LX, fig. 3 (*errore*).
1818. *Sparus vulgaris* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 349.
1835. *Sparnodus macrophthalmus* L. Agassiz, Neues Jahrb., p. 300 (name only).
1835. *Sparnodus ovalis* L. Agassiz, *ibid.*, p. 300 (name only).
1835. *Sparnodus altivelis* L. Agassiz, *ibid.*, p. 300 (name only).
1835. *Sparnodus micracanthus* L. Agassiz, *ibid.*, p. 300 (name only).
1839. *Sparnodus macrophthalmus* L. Agassiz, Poiss. Foss., Vol. IV, p. 158, pl. XXVIII, fig. 3.
1839. *Sparnodus ovalis* L. Agassiz, *ibid.*, p. 161, pl. XXIX, fig. 2. (Imperfect fish; Paris Museum of Natural History.)
1839. *Sparnodus altivelis* L. Agassiz, *ibid.*, p. 162, pl. XXIX, fig. 3. (Ditto.)
1839. *Sparnodus micracanthus* L. Agassiz, *ibid.*, p. 164, pl. XXVIII, fig. 2, pl. XXIX, fig. 1. (Ditto).
1886. *Sparnodus lethriniformis* W. Szajnocha, Pamiet. Wydz. matem.-przyr. Akad. Umiejet. Krakow, Vol. XII, p. 106, pl. I, fig. 1. (Imperfect fish; University Geological Museum, Cracow).
1876. *Sparnodus ovalis* F. Bassani, Atti. Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 177.
1876. *Sparnodus micracanthus* F. Bassani, *ibid.*, p. 177.
1901. *Sparnodus macrophthalmus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 525.

Type.—Imperfect fish; Paris Museum of Natural History.

This, the type species, is represented by numerous examples in the collection which are indicated as follows: 4000, 4000*a*, 4001, 4002, 4002*a*, 4004, 4536, 4538, 4538*a*, 4544, 4543, 4535, 4538, 4538*a*, 4461 (its counterpart = No. 4337), 4462, 4460, 4005 and 4005*a* (distorted specimen), 4503, 4537, 4537*a*, 4354, 4539, 4317 (=counterpart of 4462), 4329, 4336, 4535.

40. **Sparnodus elongatus** Agassiz. (Plate XCI, fig. 3; Plate XCVIII, fig. 2.)

1796. *Perca radula* ? G. S. Volta, Ittiolit. Veronese, p. 134, pl. XXXI, fig. 1 (*errore*).
1796. *Sparus chromis* G. S. Volta, *ibid.*, p. 138, pl. XXXII, fig. 1 (*errore*).
1796. *Sparus salpa* G. S. Volta, *ibid.*, p. 230, pl. LVI, fig. 1 (*errore*).
1835. *Sparnodus elongatus* L. Agassiz, Neues Jahrb., p. 300 (name only).

1835. *Serranus ventralis* L. Agassiz, *ibid.*, p. 293 (name only).

1839. *Serranus ventralis* L. Agassiz, Poiss. Foss., Vol. 4, p. 104, pl. XXIII*b* (lower figure). (Imperfect fish; Paris Museum of Natural History).

1839. *Sparnodus elongatus* L. Agassiz, *ibid.*, p. 165, pl. XXVIII, fig. 1.

1901. *Sparnodus elongatus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 526.

Type.—Imperfect fish; Paris Museum of Natural History.

The following mentioned specimens in the collection are referable to this species: 4540, 4541, 4541*a*, 4542, 4542*a*, 4416, 4447. Nos. 4416 and 4542 are illustrated in the accompanying plates.

Family Pomacentridæ.

Genus Odonteus Agassiz.

To this extinct genus have been assigned two small-sized species from the Eocene of Monte Bolca, neither of which is represented in the collections of the British Museum, and only the following one is in the Carnegie Institute.

41. **Odonteus sparoides** Agassiz. (Plate XCVII, fig. 1.)

1839. *Odonteus sparoides* L. Agassiz, Poiss. Foss., Vol. IV, p. 178, pl. XXXIX, fig. 2.

1876. *Odonteus sparoides* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 176.

1898. *Odonteus sparoides*, var. *depressus* F. Bassani, Palæont. Italica, Vol. III, p. 83, pl. VIII, fig. 2.

Type.—Imperfect fish; Paris Museum of Natural History.

One example of this rare form is preserved in the collection, cataloged as No. 4208. It is shown of the natural size in Plate XCVII, fig. 1.

Division D. CHÆTODONTIFORMES.

As *Perciformes*, but brain-case very short, and facial region of skull much produced, with terminal small mouth.

Family Chætodontidæ.

This group comprises about two hundred living marine species from the tropics, mostly of small size and remarkable for their singular forms and markings, and brilliant coloration. They are particularly abundant about volcanic rocks and coral reefs.

Genus Pygæus Agassiz.

42. **Pygæus nuchalis** Agassiz.

1835. *Pygæus nuchalis* L. Agassiz, Neues Jahrb., p. 302.

1838–44. *Pygæus nuchalis* L. Agassiz, Poiss. Foss., Vol. IV, pp. 16,* 255, pl. XLIV, fig. 2.

Type.—Imperfect fish; Paris Museum of Natural History.

This unsatisfactorily known form is not represented in the collections of the British Museum. A single small example in the Bayet Collection, cataloged as No. 4232, is doubtfully referable to this position, and with it may be placed the fragment numbered 4217.

Genus Ephippus Cuvier.

43. **Ephippus rhombus** (Blainville). (Plate XCII, fig. 2.)

1796. *Chætodon mesoleucus* G. S. Volta, Ittiolit. Veronese, p. 41, pl. X, fig. 1 (*errore*).

1796. *Chætodon chirurgus* G. S. Volta, *ibid.*, p. 177, pl. XLIII.

1818. *Chætodon chirurgus* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 353.

1818. *Chætodon rhombus* H. D. de Blainville, *ibid.*, p. 353.

1823. *Chætodon rhomboides* J. F. Krüger, Gesch. Urwelt, pt. II, p. 671.

1842–44. *Ephippus longipennis* L. Agassiz, Poiss. Foss., Vol. IV, pp. 15, 225, pl. XL. (Imperfect fish; Paris Museum of Natural History.)

1859. *Ephippus longipennis* A. B. Massalongo, Specimen Photogr. Anim. Foss. Agr. Veron., p. 34, pl. IX.

1901. *Ephippus rhombus* A. S. Woodward, British Museum Catalogue Fossil Fishes, pt. IV, p. 559.

Type.—Imperfect fish; Paris Museum of Natural History.

One fine example of this species is preserved in the Bayet Collection, cataloged as No. 4463 + 4463*a*. It is somewhat smaller than the type, although nearly as perfect, but fails to display ova in the abdominal cavity as some others do. No. 4463 is illustrated in Plate XCII, fig. 2.

44. **Ephippus oblongus** Agassiz.

1796. *Chætodon asper* G. S. Volta, Ittiolit. Veronese, p. 90, pl. XX, fig. 1.

1818. *Chætodon substriatus* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 352.

1835. *Ephippus oblongus* L. Agassiz, Neues Jahrb., p. 292.

1839–44. *Ephippus oblongus* L. Agassiz, Poiss. Foss., Vol. IV, pp. 15, 228, pl. XXXIX, fig. 3.

Type.—Imperfect fish; Paris Museum of Natural History.

No example of this species is to be found in the British Museum collections, and but one in the Bayet Collection of the Carnegie Institute. This is an imperfectly preserved fish cataloged as No. 5238.

Genus SCATOPHAGUS.

45. **Scatophagus frontalis** Agassiz.

1796. *Chætodon argus* G. S. Volta, Ittiolit. Veronese, p. 44, pl. X, fig. 2 (*errore*).

1831. *Chætodon argus* Cuvier and Valenciennes, Hist. Nat. Poiss., Vol. VII, p. 145 (*errore*).

1835. *Scatophagus frontalis* L. Agassiz, Neues Jahrb., p. 291.

1839–42. *Scatophagus frontalis* L. Agassiz, Poiss. Foss., Vol. IV, p. 231, pl. XXXIX, fig. 4.

1859. *Scatophagus frontalis* A. B. Massalongo, Specimen Photogr. Anim. Foss. Agr. Veron., p. 32, pl. VIII.

Type.—Imperfect fish; Paris Museum of Natural History.

Unrepresented in most foreign collections, including that of the British Museum, this species may be studied to excellent advantage from the fine suite of specimens belonging to the Carnegie Museum. These are cataloged under the following numbers: 4014, 4014*a*, 4021, 4355, 5355*a*, 4463, 4463*a*, 4464, 4449, 4449*a*, 4452, 5239, 4450 and its counterpart No. 4478.

Family ACRONURIDÆ.

These are herbivorous, partly carnivorous, fishes common in tropical seas in the vicinity of coral reefs. The existing genera *Naseus* and *Acanthurus* have Eocene representatives.

Genus NASEUS Cuvier.

The skeleton of the existing *Naseus brevirostris* is described by Dr. Günther in his Catalogue of Fishes in the British Museum, Vol. 3, 1861, p. 349.

46. **Naseus nuchalis** Agassiz.

1796. *Chætodon nigricans* G. S. Volta, Ittiolit. Veronese, p. 100, pl. XXII, fig. 1.

1835. *Naseus nuchalis* L. Agassiz, Neues Jahrb., p. 292.

1838–42. *Naseus nuchalis* L. Agassiz, Poiss. Foss., Vol. IV, pp. 13, 212, pl. XXXVI, fig. 2.

Type.—Imperfect fish; Paris Museum of Natural History.

This rare form is represented in the Bayet Collection of the Carnegie Museum by an exceedingly handsome specimen, cataloged as No. 4454.

47. **Naseus rectifrons** Agassiz. (Plate XCVII, fig. 2.)

1796. *Chætodon triostegus* G. S. Volta, Ittiolit. Veronese, p. 143, pl. XXXIII (*errore*).

1818. *Chætodon triostegus* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 354.

1838–42. *Naseus rectifrons* L. Agassiz, Poiss. Foss., Vol. IV, pp. 13, 213, pl. XXXVI, fig. 3.

1859. *Naseus rectifrons* A. B. Massalongo, Specimen Photogr. Anim. Foss. Agr. Veron., p. 22, pl. XII, fig. 1.

1876. *Naseus rectifrons* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 178.

1901. *Naseus rectifrons* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 565.

Type.—Imperfect fish; Paris Museum of Natural History.

Two examples of this species are preserved in the Bayet Collection, one small and imperfect, the other a fine large example, both in counterpart. These are cataloged under the numbers 4441 and 4362 (in counterpart), No. 4441*a* is the specimen illustrated in Plate XCVII, Fig. 2. The British Museum possesses three specimens.

Genus Acanthurus Forskål.

With lateral caudal spines; spinous portion of dorsal fin less extended than articulated portion; anal fin with three spines.

For a description of the skeleton of the existing *A. triostegus*, by Dr. Günther, see Cat. Fishes Brit. Mus. (1861), Vol. III, p. 327.

No fossil representatives of this genus are preserved in the British Museum, nor are examples of either of the species described by Agassiz from the Eocene of Monte Bolca to be found in the collections of the Carnegie Museum. One specimen occurs, however, catalogued as No. 4342, and having a total length of 15 cm., which probably belongs to an undescribed species of this genus.

Division ZEORHOMBI.

Family Amphistiidæ.

This extinct family, known only by the Upper Eocene *Amphistium paradoxum*, originally described as a *Pleuronectes*, is placed by Boulenger in close association

with the Zeidæ, from which it differs in the smaller number of vertebræ (10+14), and in having the dorsal and anal spines more reduced, adnate, and continuous with the series of soft rays. Ventral fins with one spine and eight soft rays. This fish, according to the author just mentioned, appears to realize in every respect

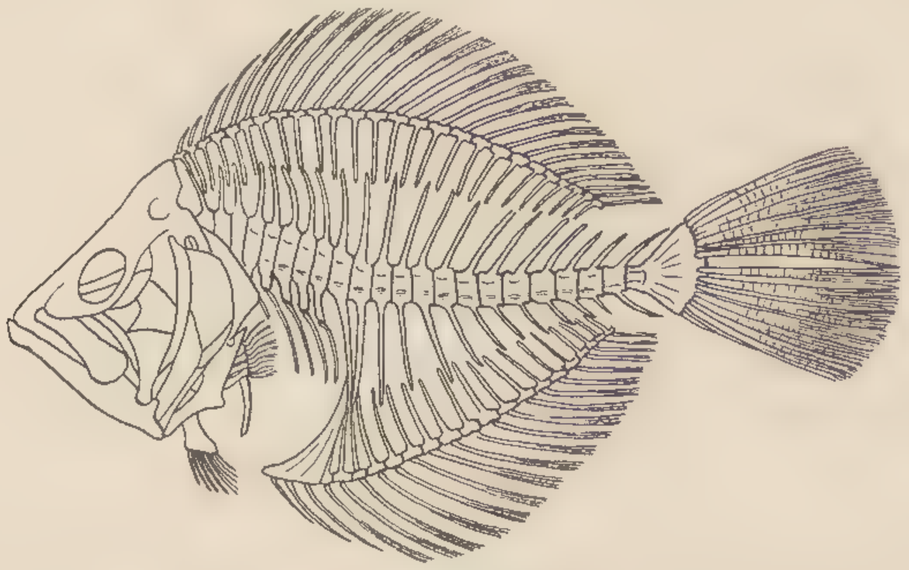

FIG. 4. *Amphistium paradoxum* Agassiz. Upper Eocene, Monte Bolca, Italy. Restored after Boulenger. About one half natural size.

the prototype of the Pleuronectidæ before they had assumed the asymmetry which characterizes them as a group. No examples of *Amphistium* are contained in the collection.

Family PLEURONECTIDÆ.

This family first appears in the Upper Eocene of Monte Bolca, but no extinct genera are recognizable. Modern Flat-fishes form a large group of some 500 species, mostly marine, but a few species related to the Soles are confined to fresh water.

Genus RHOMBUS (Klein) Cuvier.

48. **Rhombus minimus** Agassiz. (Plate XCVI, fig. 3.)

1796. *Pleuronectes quadratulus* G. S. Volta, Ittiolit. Veronese, p. 260, pl. LXIII, fig. 3 (*errore*).

1835. *Rhombus minimus* L. Agassiz, Neues Jahrb., p. 301 (name only).

1839–42. *Rhombus minimus* L. Agassiz, Poiss. Foss., Vol. IV, p. 289, pl. XXXIV, fig. 1.

1859. *Rhombus minimus* A. B. Massalongo, Specimen Photogr. Anim. Foss. Agr. Veron. (1859), p. 36, pl. XIII, fig. 1.

1901. *Rhombus minimus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, Pt. IV, p. 607.

Type.—Nearly complete fish; Paleontological Museum, Munich.

Two good examples of this species are preserved in the collection of the British Museum, and as many in that of the Carnegie Museum. These are cataloged as follows: 4433, 4433*a*, 4457, 4457*a*. One of these is shown in Plate XCVI, fig. 3.

Division GOBIIFORMES.

According to Boulenger the Gobies, which constitute this division, are not very remote from the *Perciformes*, and may have evolved out of a type not very different from the *Percidæ*.

Synopsis of Families represented by Extinct Genera or Species.

All abdominal vertebræ with large transverse processes supporting ribs.... *Gobiidæ*.
Abdominal vertebræ without transverse processes..... *Trachinidæ*.

Family Gobiidæ.

The so-called *Gobius microcephalus* Agassiz, the systematic position of which is doubtful, may be provisionally retained in this family, to which Agassiz first assigned it. The typical specimen is preserved in the British Museum of Natural History, and another, nearly as perfect, in the Bayet Collection of the Carnegie Museum (No. 4504). This is shown in Plate XCVI, fig. 4, twice enlarged.

Family Trachinidæ.

Genus Callipteryx Agassiz.

This extinct genus is known only by two species from the marine Upper Eocene of Italy.

49. **Callipteryx speciosus** Agassiz. (Plate CI, fig. 1.)

1796. *Gadus merluccius* G. S. Volta, Ittiolit. Veronese, p. 72, pl. XV (*errore*).
1835. *Callipteryx speciosus* L. Agassiz, Neues Jahrb., p. 293 (name only).
1838–42. *Callipteryx speciosus* L. Agassiz, Poiss. Foss., Vol. IV, pp. 12, 196, pl. XXXIII, fig. 2.
1901. *Callipteryx speciosus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 589.

Type.—Imperfect fish; Paris Museum of Natural History.

This is a large form, attaining a total length of about 70 cm. It is not represented in the collections of the British Museum, but two fine specimens belonging to it are preserved in the Carnegie Museum. These are cataloged as Nos. 4404 (in counterpart) and 5244.

50. **Callipteryx recticaudus** Agassiz.

1796. *Trigla lyra* G. S. Volta, Ittiolit. Veronese, p. 121, pl. XXX (*errore*).
1835. *Callipteryx recticaudus* L. Agassiz, Neues Jahrb., p. 300 (name only).
1838–42. *Callipteryx recticaudus* L. Agassiz, Poiss. Foss., Vol. IV, pp. 12, 198, pl. XXXIII, fig. 2.
1901. *Callipteryx recticaudus* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 589.

Type.—Imperfect distorted fish; Paris Museum of Natural History.

A smaller and more slender species than the type, attaining a length of about 50 cm. One specimen is included in the published Catalog of the British Museum, and three belong to the Carnegie Museum, also a detached caudal fin, probably of this species. These bear the following departmental numbers: 4403 (in counterpart), 4207, 4313, 4518 (caudal fin in counterpart).

Division SCLEROPAREI.

Second suborbital bone more or less produced towards or anchylosed with the preoperculum ("suborbital stay"). Ventral fins thoracic.

As remarked by Boulenger, the "cheek-armoured Acanthopterygians," "Joues cuirassées" of Cuvier, after the exclusion of the Sticklebacks, form a perfectly natural association, evidently derived from the *Serranidæ*, with which the more generalized forms have much in common.

Family Cottidæ.

Descriptions and figures of the skeleton of existing *Cottidæ* are given by C. Girard, "A Monograph of the Cottoids," Smithson. Contrib., Vol. III, Art. No. 3 (1850).

Genus Eocottus. A. S. Woodward.

This extinct genus is known by a solitary species from the marine Upper Eocene of Monte Bolca. According to Heckel, this species is closely related to *Callipteryx*, but it is distinguished from that genus by the presence of scales and the short and stout form of the dermal arches in the abdominal region.

51. **Eocottus veronensis** (Volta). (Plate XCIX, fig. 1. Figure inverted.)

1796. *Gobius barbatus* G. S. Volta, Ittiolit. Veronese, p. 48, pl. XI, fig. 1.
1796. *Gobius veronensis* G. S. Volta, *ibid.*, p. 51, pl. XI, fig. 2.
1818. *Gobius veronènsis* H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 358.

1835. *Gobius macrourus* L. Agassiz, Neues Jahrb., p. 291 (name only).
1838–39. *Gobius macrurus* L. Agassiz, Poiss. Foss., Vol. IV, pp. 12, 203, pl. XXXIV, figs. 3, 4.
1876. *Gobius macrurus* F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 180.
1901. *Eocottus veronensis* A. S. Woodward, Brit. Mus. Cat. Foss. Fishes, pt. IV, p. 581.

Type.—Imperfect fish; Paris Museum of Natural History.

Of this form only one well-preseerved specimen has hitherto been known besides the type, this being the property of the British Museum of Natural History. Three examples are contained in the Bayet Collection of the Carnegie Museum, designated as follows: Cat. Nos. 4233, 4439, and 4512.

Division BLENNIIFORMES.

Pectoral fins with much extended base or flank; pelvic fins jugular, reduced or absent. Dorsal fin-spines numerous, but usually flexible. No bony stay between circumorbital ring and preoperculum.

Family Blochiidæ.

This family is known by a single Eocene genus, founded by Volta in 1796.

52. **Blochius longirostris** Volta. (Text figure 5*a*.)

1796. *Blochius longirostris* G. S. Volta, Ittiolit. Veronese, p. 53, pls. XII, LXX.
1843–44. *Blochius longirostris*, L. Agassiz, Poiss. Foss., Vol. II, pt. II, p. 255, pl. XLIV.
1887. *Blochius macropterus* A. de Zigno, Mem. R. Istit. Veneto, Vol. XXIII, p. 25, fig. 7.
1901. *Blochius longirostris* A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 593.

Type.—Imperfect fish; Paris Museum of Natural History.

This highly specialized and remarkable form, by Woodward regarded as descended from the same ancestral stock as gave rise to the Blennies, by Boulenger placed in association with the Sail-fishes (*Histiophoridæ* and extinct *Palæorhynchidæ*), is not only typical of the genus, but has remained hitherto the only known representative of it and of the family *Blochiidæ*. In all, four examples are preserved in the Bayet Collection of the Carnegie Museum, two large-sized and well-preserved individuals, and two smaller specimens, one of them evidently immature.

These are cataloged as Nos. 4500 (young example, imperfect), 4312 (small but complete), 4546 (total length 70 cm., of which the head, from base of occiput to the extremity of rostrum measures 30 cm.), and 4520 (in counterpart, total length 60 cm.).

In addition to the four specimens just mentioned, the head in natural association with a few anterior vertebræ and fin-portions of an enormous example of *Blochius*, occurs in the Bayet Collection, and is to be seen on exhibition in the Hall of Fossil Vertebrates in the Museum. Notwithstanding its imperfect condition, the form and proportion of the preserved parts are such as to leave little doubt that the huge head in question pertains to a distinct species, the description of which immediately follows.

53. **Blochius moorheadi,** sp. nov. (Text figure 5.)

Type.—Nearly complete head in natural association with anterior vertebræ and portions of the pectoral fins; Carnegie Museum.

A relatively gigantic species, estimated to have attained a total length of between 2.5 and 3 metres, thus greatly exceeding the average size of individuals belonging to the type species. Further noteworthy differences are to be seen in the general configuration and relative proportions of the head parts, especially in the gently sloping outline of the cranial roof, depressed form of the head posteriorly, and consequent shortening of the opercular apparatus. The abrupt downward slope of the facial region in advance of the orbits, which is so marked a feature in *B. longirostris* is here missing, and the orbit itself appears to be more posteriorly situated than in the type species. The vertebræ are of the usual hour-glass form, and larger than those of *Cybium* or other known contemporaries among bony fishes.

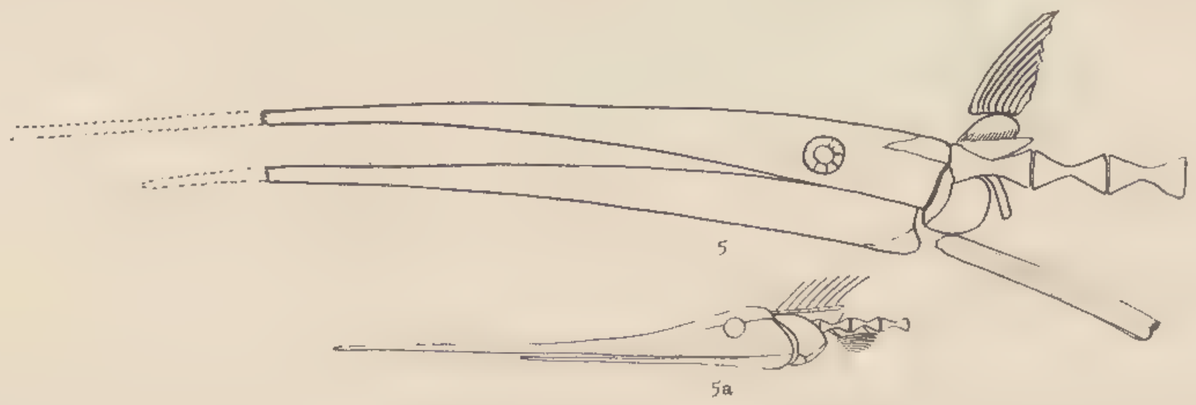

Fig. 5. *Blochius moorheadi*, sp. nov. Anterior portion of type specimen, preserved in the Carnegie Museum. Sclerotic ring partially preserved; pectoral fin-rays displaced. Greatly reduced.

Fig. 5*a*. *Blochius longirostris* Volta. Complete head and anterior portion of the trunk, showing much-elongated rostrum and form of opercular plates. (After A. S. Woodward.) ×1/10.

Owing to the crushed condition of the cheek-plates and opercular apparatus, a restoration of these parts has not been attempted in the annexed diagram, but

the probable arrangement of these parts may be inferred from a comparison with the same structure in *B. longirostris,* an outline figure of which is given above (5*a*).

The specific title proposed for this remarkable new form is bestowed in honor of Mr. Moorhead B. Holland of Pittsburgh, son of the Director of the Museum, and friend of the writer, who rendered efficient aid in the task of superintending the transfer of the Bayet Collection from Brussels to this country during the summer of 1903.

Family Blennidæ.

Elongated fishes with stout caudal pedicle, due to an expanded hypural; snout not produced. Dorsal fin occupying nearly the whole of the back, often subdivided; anal fin also much extended; caudal fin rounded or tapering.

Modern species are marine, living at the bottom near almost all coasts. Most of them are carnivorous, but a few are herbivorous; some are viviparous (*Clinus*), others oviparous. The habits of *Blennius* are interesting, and have been admirably described by Guitel (Arch. Zool. Expérim., 1893, sér. 3, Vol. I, p. 325). The male makes a sort of nest and defends the brood.

Genus Pterygocephalus Agassiz.

This extinct genus, known only from the Eocene, and erroneously identified with the existing *Cristiceps* by J. Müller, is thus diagnosed by A. Smith Woodward:

"Head short and orbit very large; mouth small, with conical teeth. Vertebræ about 10 in the abdominal, 14 in the caudal region. Dorsal fin very deep, the foremost large spine displaced forwards above the head, but the fin otherwise continuous. Squamation well developed and continuous, each scale with a longitudinal keel, and the keels forming regular lines along the trunk."

54. **Pterygocephalus paradoxus** Agassiz. (Plate XCVI, fig. 5.)

1796. *Labrus malapterus* G. S. Volta, Ittiolit. Veronese, p. 228, pl. LV, fig. 3 (*errore*).

1818. *Labrus malapterus*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., Vol. XXVII, p. 351.

1835. *Pterygocephalus paradoxus* L. Agassiz, Neues Jahrb., p. 295 (name only).

1839. *Pterygocephalus paradoxus* L. Agassiz, Poiss. Foss., Vol. IV, p. 191, pl. XXXII, figs. 5, 6.

1876. *Cristiceps paradoxus*, F. Bassani, Atti Soc. Veneto-Trent. Sci. Nat., Vol. III, p. 178.

1901. *Pterygocephalus paradoxus*, A. S. Woodward, Brit. Mus. Cat. Fossil Fishes, pt. IV, p. 595.

Type.—Imperfect fish; Paris Museum of Natural History.

Two examples of this rare and interesting species are recorded as belonging to the British Museum of Natural History, and one each is to be found in the Harvard and Pittsburgh Museums, in this country. That belonging to the latter institution is a fair specimen, showing the characteristic squamation, and cataloged under the number 4215. It is shown of twice the natural size in the accompanying plate.

Suborder PEDICULATI.

This is a small, natural group, connected with the *Acanthopterygii jugulares* through the *Batrachidæ*, in which the elongate pterygials foreshadow the kind of "arm" or pseudobrachium which generally characterizes these highly aberrant Fishes. Dr. Theodore Gill has recently contributed a valuable paper on this group.

Family ANTENNARIIDÆ.

"Mouth large, vertical or very oblique, turned upwards, with cardiform teeth. Gill-opening in or behind lower axil of pectoral; no pseudobranchiæ. Pectoral fin forming an elbow-like angle, with three pterygials. Ventral with four or five rays. Spinous dorsal present. Skin naked or spinulose."

According to Dr. Boulenger, from whom we have taken the above family diagnosis, this group comprises about forty recent species, distributed among five genera: *Pterophryne, Antennarius, Brachionichthys, Saccarius,* and *Chaunax.* "The species of *Antennarius,*" says the same author, "live mostly in coral groves, where they lie in wait for prey, well-concealed by the protective coloration and the harmonizing aspect of their integument and appendages. To this genus also belongs the 'Marbled Angler' (*A. marmoratus*), carried about in mid-ocean among the *Sargassum* weed, to rest on which, from its peculiar arm-like pectoral fins, it is especially fitted; there it makes its wonderful nest of silk-like fibres probably secreted by the parent as in the Sticklebacks, with large bundles of eggs hanging like grape clusters."

Genus HISTIONOTOPHORUS Eastman.

(Syn. *Histiocephalus* Zigno.)

This extinct genus, known only by the typical species, is one of the rarest of all the components of the Eocene fish-fauna of Monte Bolca. Its systematic relations have been discussed by Dr. Theodore Gill and the present writer, and attention has been called to it as a remarkable instance of a form of fish-life appearing suddenly in the Eocene, already highly modified, without any known predecessors nor any that can be plausibly conjectured, but which persists after its first

introduction essentially unchanged until modern times. In the opinion of Dr. Gill, its nearest allies in the existing fauna are to be found in *Antennarius* itself and *Pterophryne*.

55. **Histionotophorus bassani** (Zigno).

1887. *Histiocephalus bassani* A. de Zigno, Mem. R. Istit. Veneto, XXIII, p. 31, fig. 9.

1904. *Histionotophorus bassani* C. R. Eastman, Bull. Mus. Comp. Zool., XLVI, p. 32, pl. 1, figs. 1–3, text fig. *c*.

1904. *Histionotophorus bassani* T. Gill, *Science*, n. s., p. 845.

Besides the type and three well-preserved specimens that are now the property of the Museum of Comparative Zoology at Cambridge, Mass., but one other representative of this species is known. It is a small form in the Bayet Collection of the Carnegie Museum, cataloged as No. 5237.

Suborder Plectognathi.

This is a highly aberrant group, closely connected with the *Acanthopterygii* through the *Acanthuridæ*, as pointed out long ago by Dareste (*Ann. Sci. Nat. Zool.* (3), xiv, 1850, p. 105). These fishes have usually been arranged in three divisions: *Sclerodermi*, *Ostracodermi*, and *Gymnodontes*, but Mr. C. T. Regan has shown reasons for combining the second of these with the first and third. Following is Boulenger's diagnosis of the latter of these divisions:

Division GYMNODONTES.

"Supraclavicle oblique, sometimes nearly horizontal; lower three pectoral pterygials enlarged and immovably united to the coraco-scapular cartilage, upper pterygial small, suturally united to the scapula. Anterior vertebræ with bifid divergent neural spines. Basis cranii simple; suture between dentary and articular elements evident. Pelvis absent."

The above definition of this group is further characterized by the same author as follows: "The spinous dorsal and the ventral fins are constantly absent, the premaxillaries are united to the maxillaries, and the teeth are coalescent, forming a beak; parapophyses are not developed, and epipleurals are absent.

Family Diodontidæ.

Beak without median suture. Interoperculum rod-like, attached posteriorly to the rod-like anterior limb of the suboperculum. Gills 3. All the precaudal vertebræ with bifid neural spines. Skin with movable spines; vertebræ 21 or 22.

Of the two modern genera comprised by this family, *Diodon* and *Lyosphæra*, the former occurs fossil from the Eocene onwards and is represented by numerous species. Only a few are known from the Upper Eocene horizon of Monte Bolca, the most important being *D. erinaceus* and *D. tenuispinus* Agassiz. Examples of both of these occur in the Bayet Collection of the Carnegie Museum, and are cataloged under the following numbers: 4498 (*D. erinaceus* Agassiz); 4442, 4443 (*D. tenuispinus* Agassiz).

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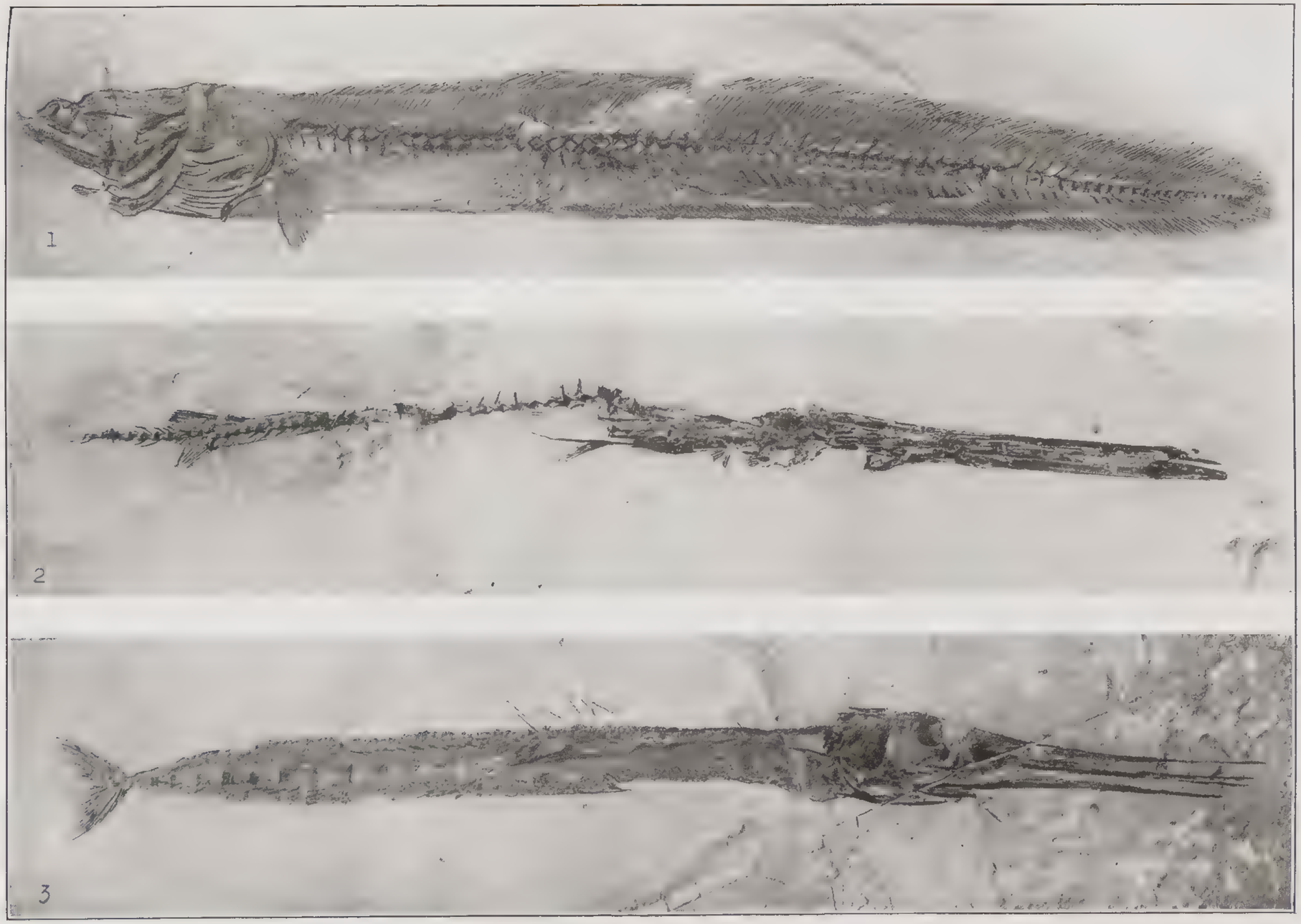
EXPLANATION OF PLATES.

Plate XC.

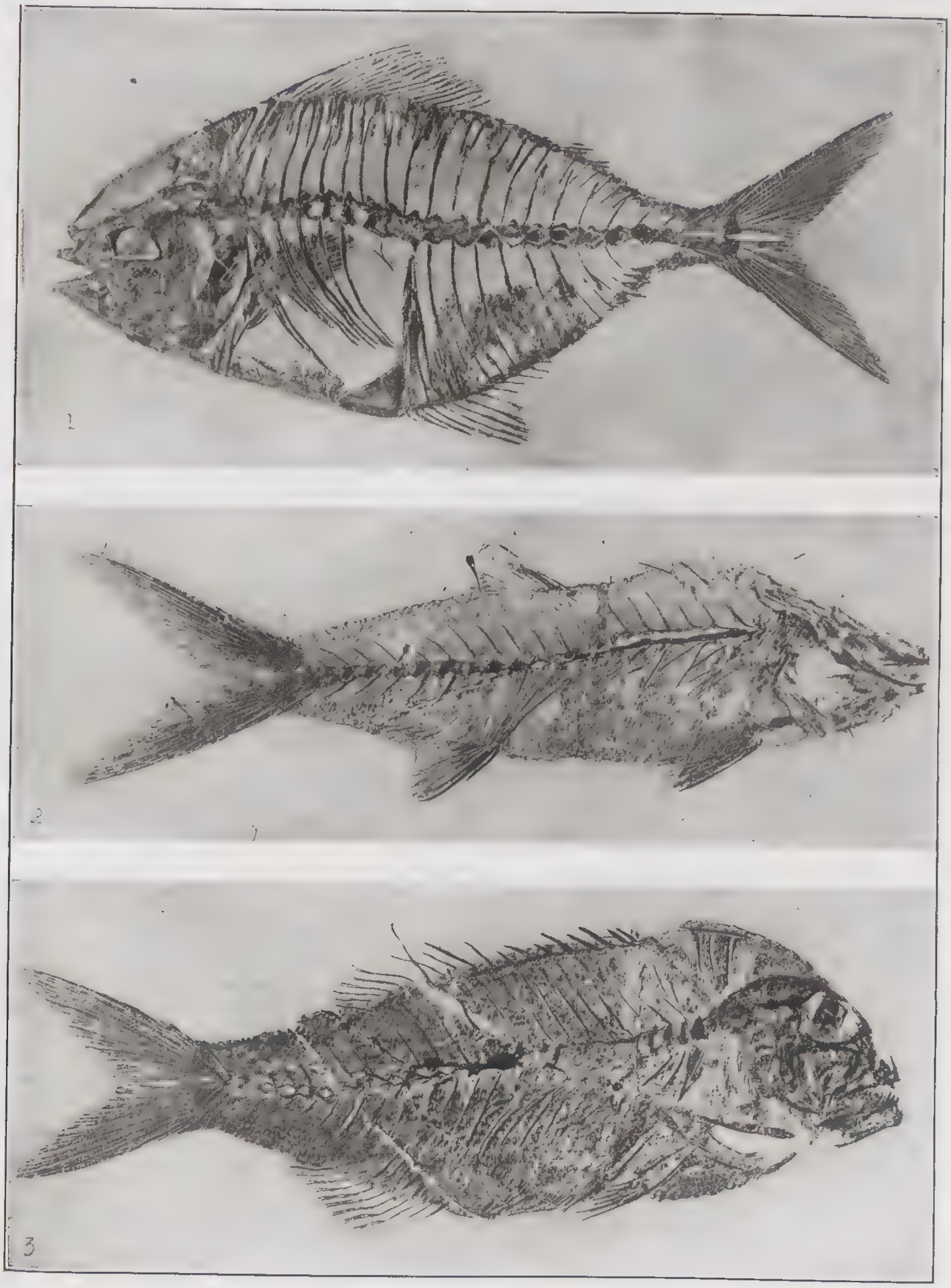
Fig. 1. *Eomyrus formosissimus* Eastman (*ex* Agassiz MS.). C. M. Cat. 5233. ×5/6.
Fig. 2. *Urosphen dubia* (Blainville). C. M. Cat. No. 4015. ×6/7.
Fig. 3. *Blochius longirostris* Volta. Immature example. C. M. Cat. No. 4312. ×8/9.



1. *Eomyrus formosissimus* EASTMAN, $\frac{5}{6}$. 2. *Urosphen dubia* (BLAINVILLE), slightly reduced. 3. *Blochius longirostris* VOLTA, somewhat reduced. $\frac{1}{5}$.

Plate XCI.

Fig. 1. *Trachynotus tenuiceps* Agassiz. C. M. Cat. No. 4532. ×1/1.
Fig. 2. *Carangopsis dorsalis* Agassiz. C. M. Cat. No. 4537. × 1/1.
Fig. 3. *Sparnodus elongatus* Agassiz. C. M. Cat. No. 4542. ×1/1.



1. *Trachynotus tenuiceps* AGASSIZ. $\times \frac{1}{1}$.
2. *Carangopsis dorsalis* AGASSIZ. $\times \frac{1}{1}$.
3. *Sparnodus elongatus* AGASSIZ. $\times \frac{1}{1}$.

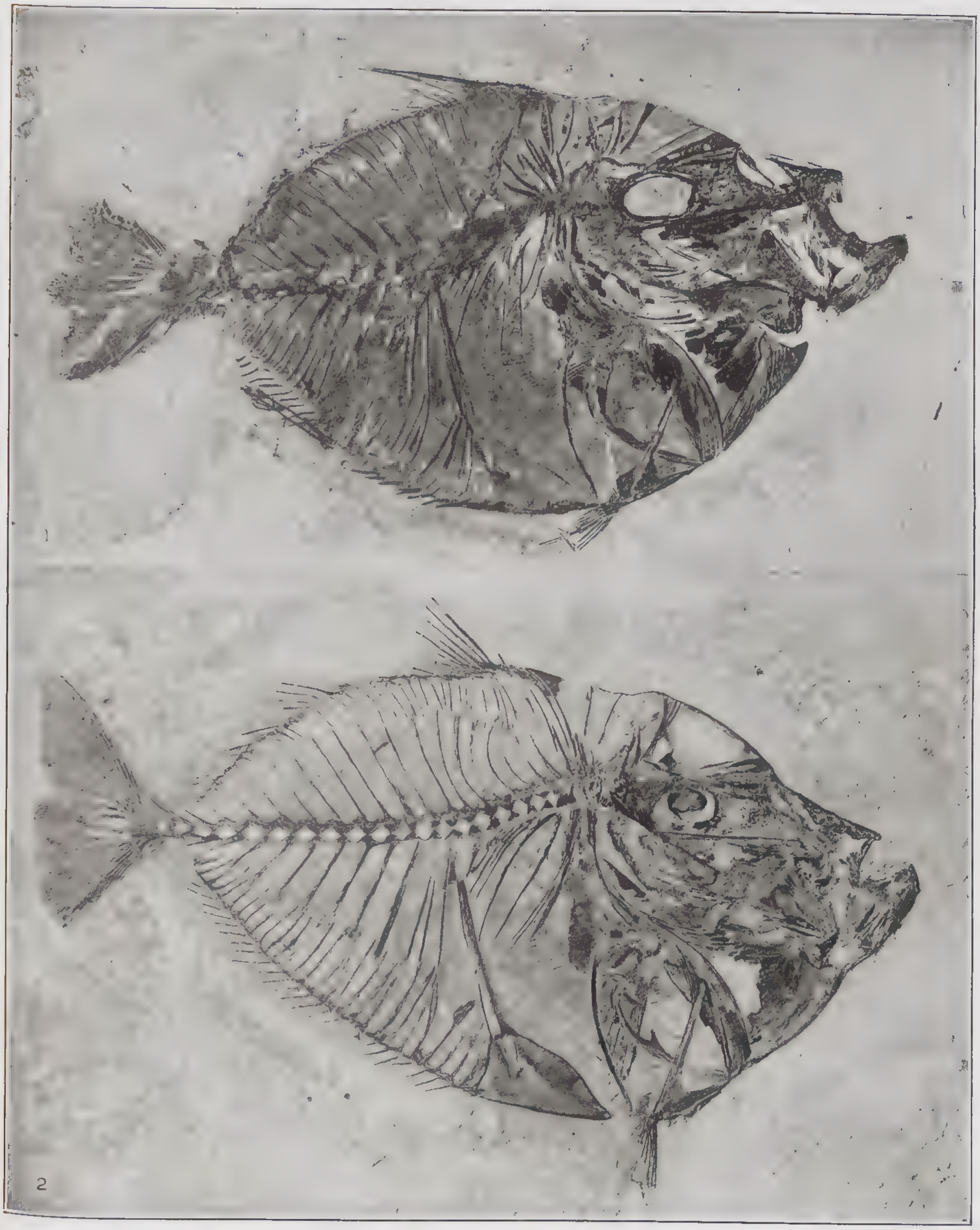
Plate XCII.

Fig. 1. *Holocentrum macrocephalum* (Blainville). C. M. Cat. No. 4455. Reduced 1/5.
Fig. 2. *Ephippus rhombus* (Blainville). C. M. Cat. No. 4463. Reduced 1/5.
Fig. 3. *Mene oblonga* (Agassiz). C. M. Cat. No. 4020. Reduced 1/5.

1. *Holocentrum macrocephalum* (BLAINVILLE). Reduced $\frac{1}{5}$.
2. *Ephippus rhombus* (BLAINVILLE). Reduced $\frac{1}{5}$.
3. *Mene oblonga* (AGASSIZ). Reduced $\frac{1}{5}$.

Plate XCIII.

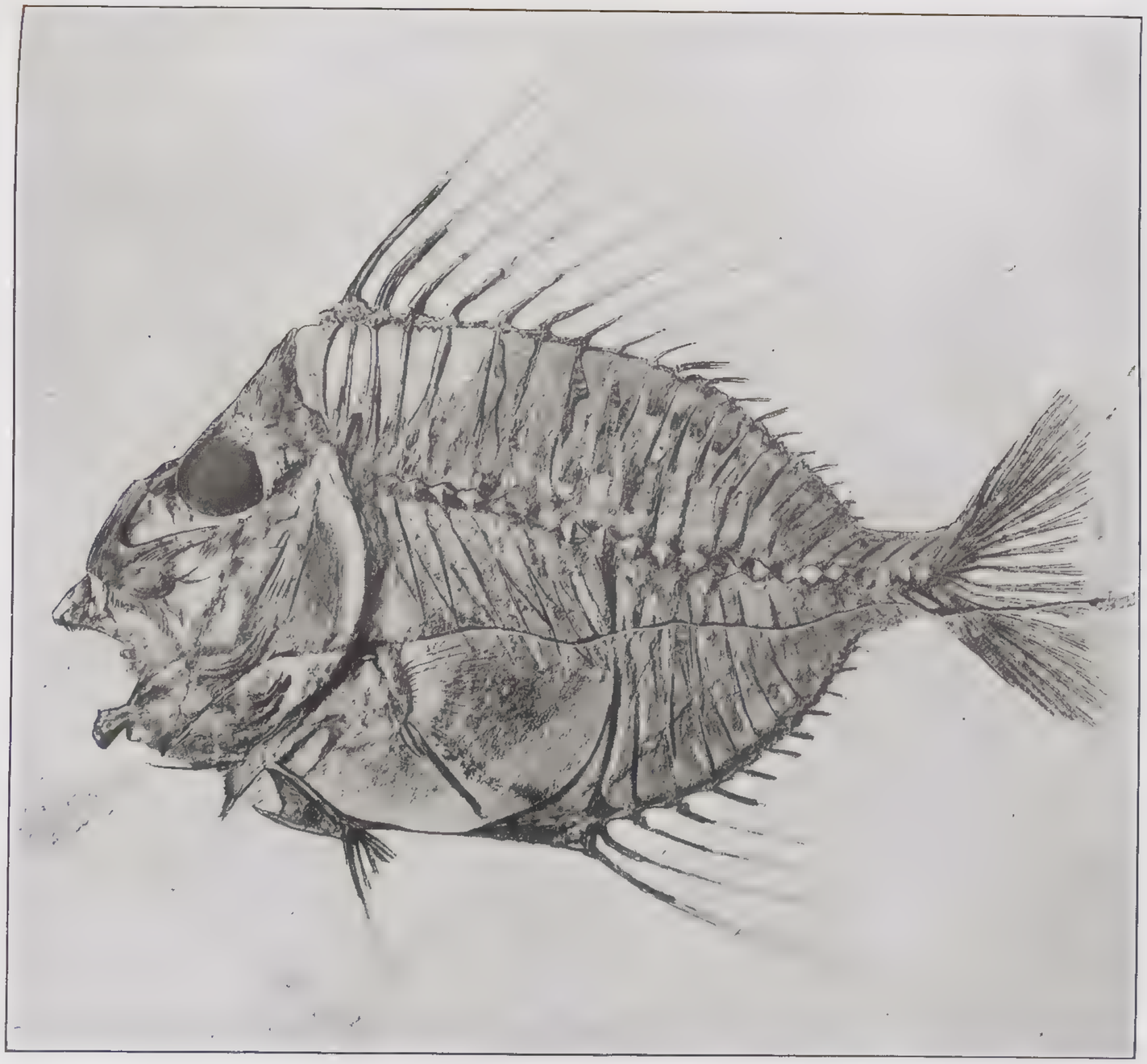
Fig. 1. *Vomeropsis longispinus* Agassiz. C. M. Cat. No. 4489*a*. × 1/1.
Fig. 2. *Vomeropsis longispinus* Agassiz. C. M. Cat. No. 4350. × 1/1.



1–2. *Vomeropsis longispinus* AGASSIZ. Figures slightly reduced. $\frac{1}{5}$.

PLATE XCIV.

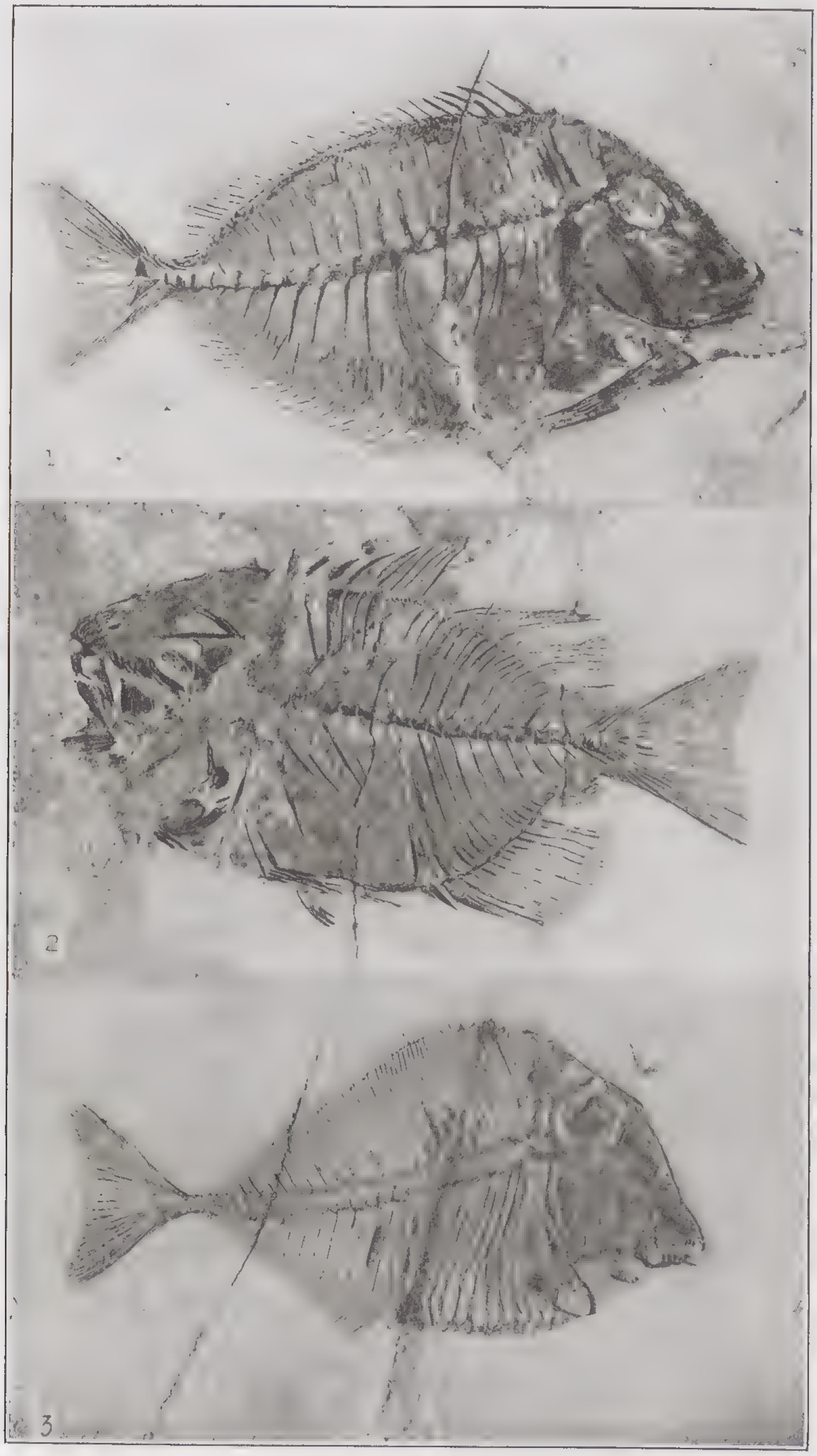
Acanthonemus subaureus (Blainville). C. M. Cat. No. 4439. ×14/15.



Acanthonemus subaureus BLAINVILLE. $\frac{14}{15}$ natural size.

PLATE XCV.

Fig. 1. *Naseus nuchalis* Agassiz. C. M. Cat. No. 4454. ×1/1.
Fig. 2. *Ephippus oblongus* Agassiz. C. M. Cat. No. 5238. ×1/1.
Fig. 3. *Pycnodus gibbus* Agassiz. C. M. Cat. No. 4480. ×1/1.



1. *Naseus nuchalis* AGASSIZ. $\times \frac{1}{1}$.
2. *Ephippus oblongus* AGASSIZ. $\times \frac{1}{1}$.
3. *Pycnodus gibbus* AGASSIZ. $\times \frac{1}{1}$.

PLATE XCVI.

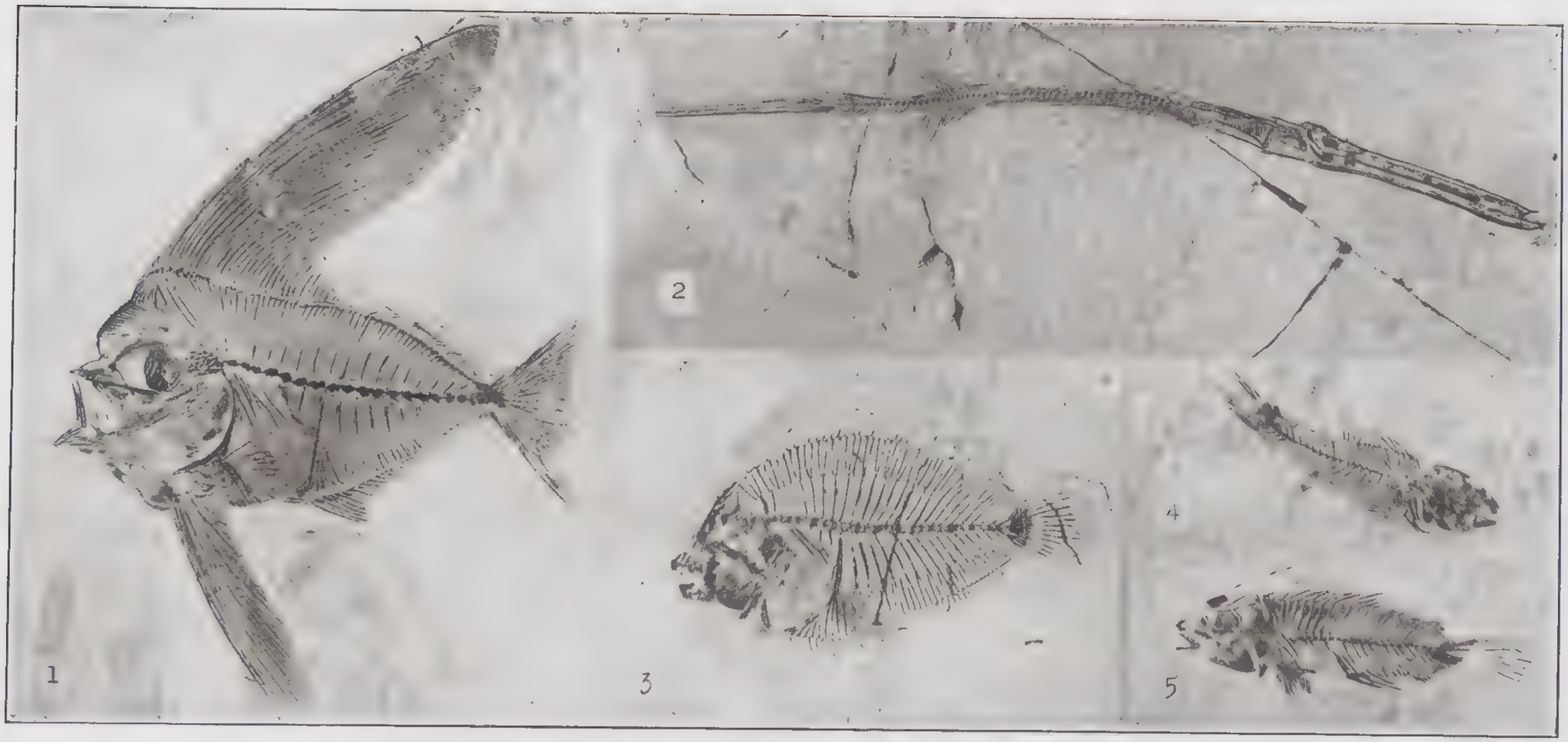
Fig. 1. *Semiophorus velifer* (Volta). C. M. Cat. No. 4467. Original specimen previously figured by Massalongo. Slightly reduced.

Fig. 2. *Urosphen dubia* (Blainville). C. M. Cat. No. 4499. Slightly reduced.

Fig. 3. *Rhombus minimus* Agassiz. C. M. Cat. No. 4457. ×1/1.

Fig. 4. *Gobius microcephalus* Agassiz. C. M. Cat. No. 4504. 2/1.

Fig. 5. *Pterygocephalus paradoxus* Agassiz. C. M. Cat. No. 4215. ×2/1.

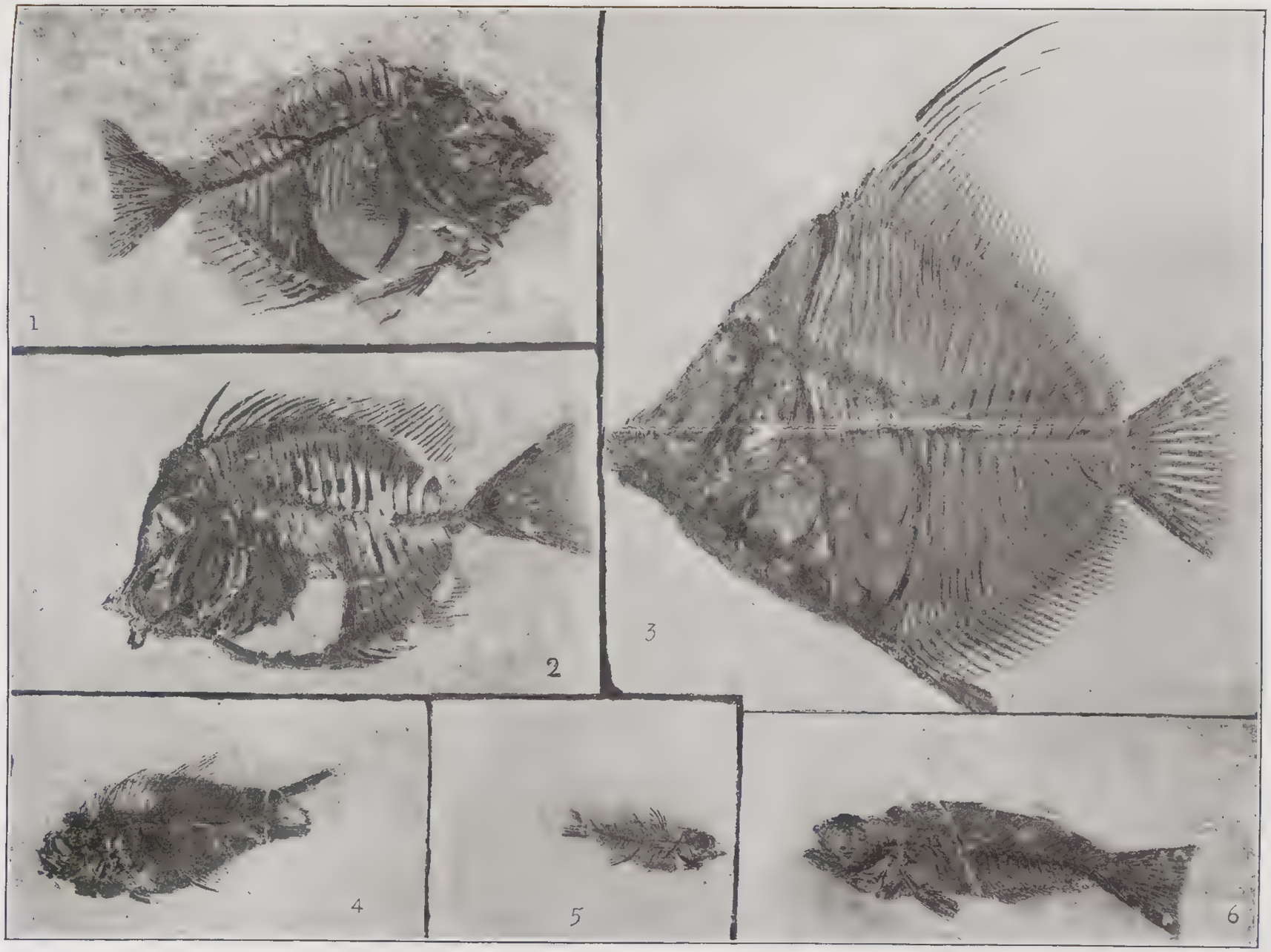


1. *Semiophorus velifer* (VOLTA). 2. *Urosphen dubia* (BLAINVILLE). 3. *Rhombus minimus* AGASSIZ. $\times \frac{1}{1}$. 4. *Gobius microcephalus* AGASSIZ. $\times \frac{2}{1}$.
5. *Pterygocephalus paradoxus* AGASSIZ. $\times \frac{2}{1}$.

Plate XCVII.

(All figures natural size.)

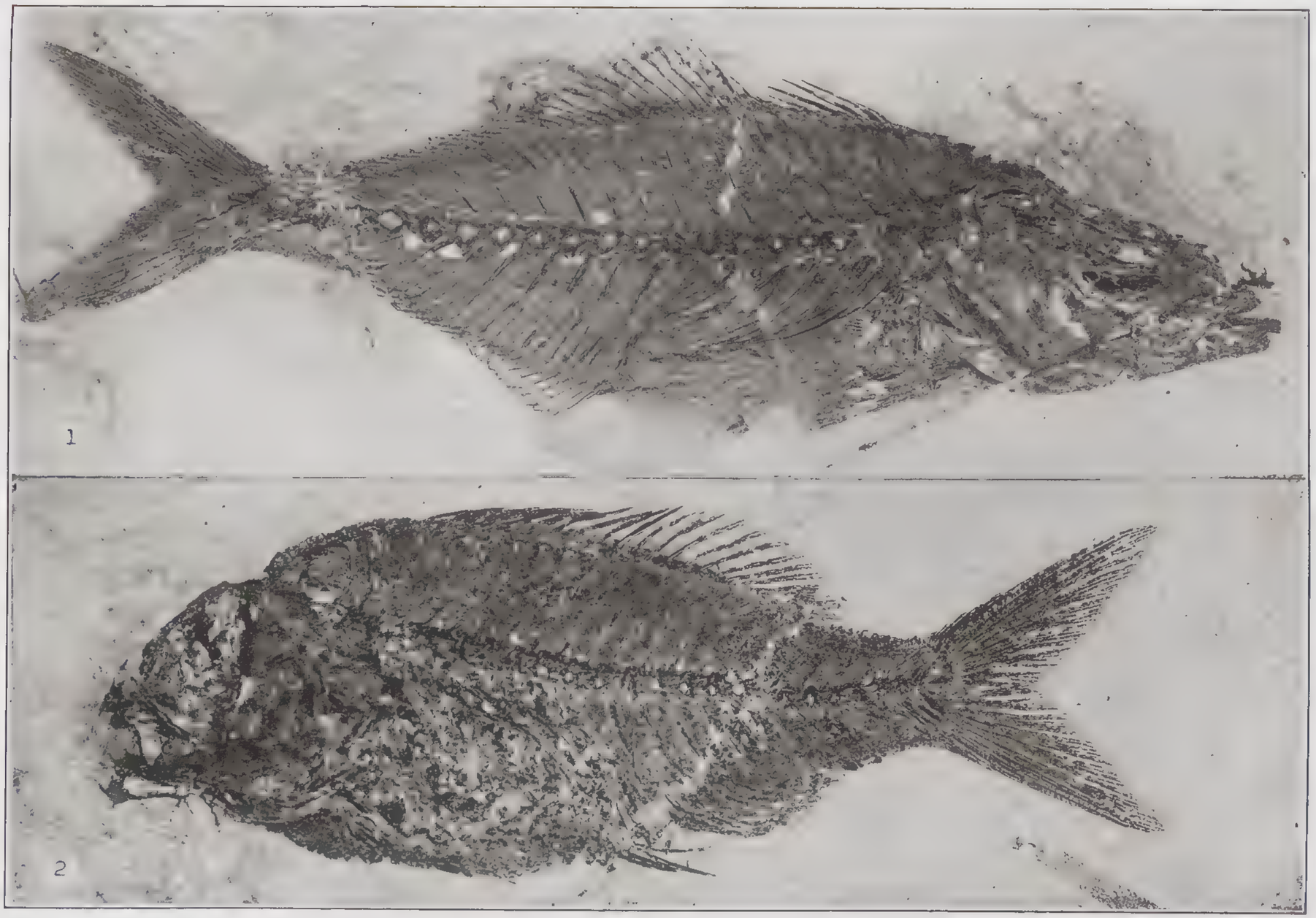
Fig. 1. *Odonteus sparoides* Agassiz. C. M. Cat. No. 4208.
Fig. 2. *Naseus rectifrons* Agassiz. C. M. Cat. No. 4441a.
Fig. 3. *Zanclus brevirostris* Agassiz. C. M. Cat. No. 4415.
Fig. 4. *Cyclopoma micracanthum* (Agassiz). C. M. Cat. No. 4228.
Fig. 5. *Cyclopoma pygmæum* (Agassiz). C. M. Cat. No. 4212.
Fig. 6. *Seriola* (*Lichia*) *prisca* (Agassiz), juv. C. M. Cat. No. 4230.



1. *Odonteus sparoides* AGASSIZ. 2. *Naseus rectifrons* AGASSIZ. 3. *Zanclus brevirostris* AGASSIZ. 4. *Cyclopoma micracanthum* (AGASSIZ). 5. *C. pygmæum* (AGASSIZ). 6. *Seriola* (*Lichia*) *prisca* (AGASSIZ) juv.
(All figures natural size.)

PLATE XCVIII.

Fig. 1. *Seriola* (*Lichia*) *prisca* (Agassiz). Car. Mus. Cat. No. 4298. ×1/1.
Fig. 2. *Sparnodus elongatus* Agassiz. Car. Mus. Cat. No. 4416. 1/1.



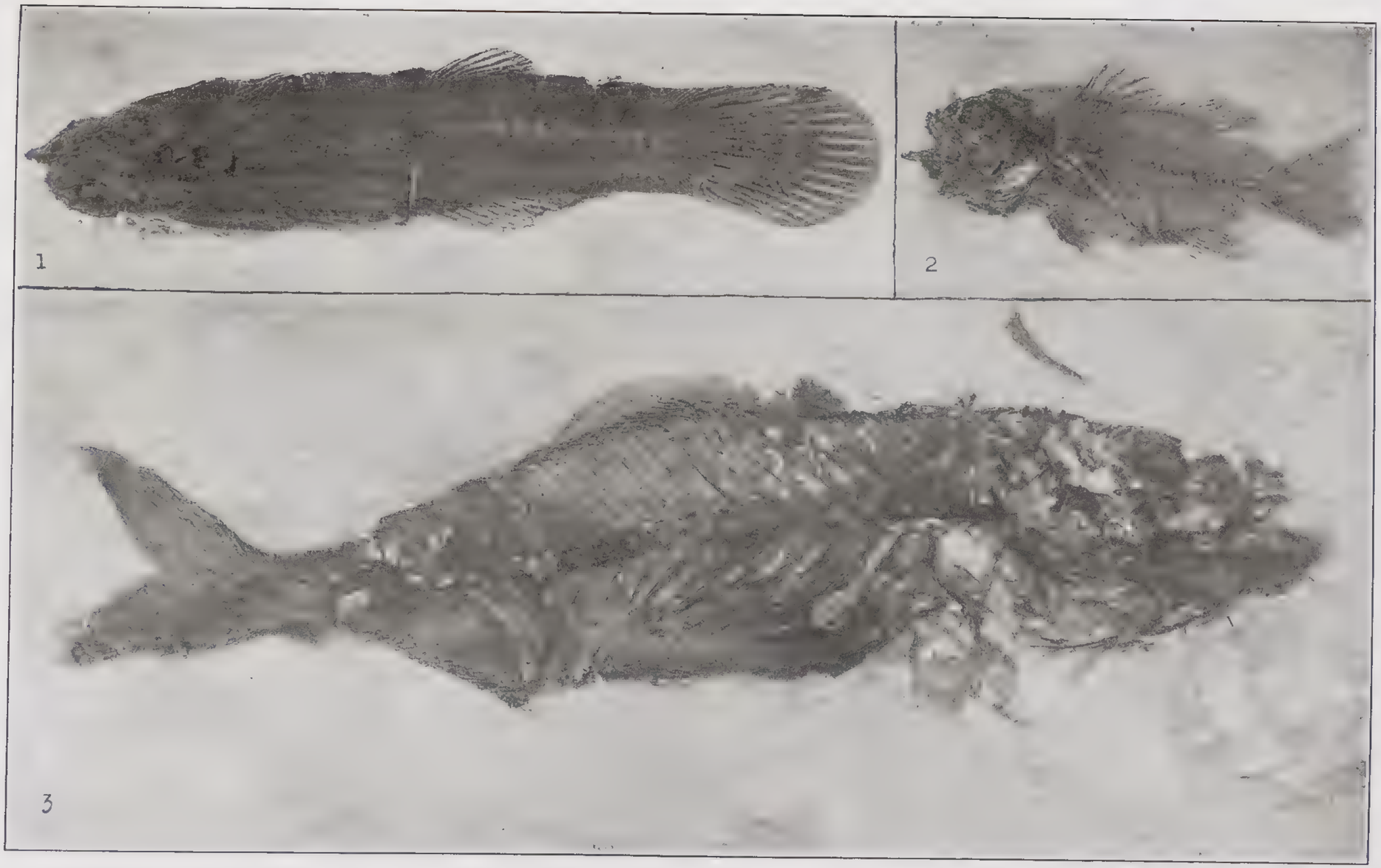
1. *Seriola* (*Lichia*) *prisca* (AGASSIZ). × $\frac{1}{4}$. 2. *Sparnodus elongatus* AGASSIZ. × $\frac{1}{4}$.

Plate XCIX.

Fig. 1. *Eocottus veronensis* (Volta). Figure inverted. Car. Mus. Cat. No. 4439. ×1/1.

Fig. 2. *Lates gracilis* Agassiz, juv. Car. Mus. Cat. No. 4501. ×1/1.

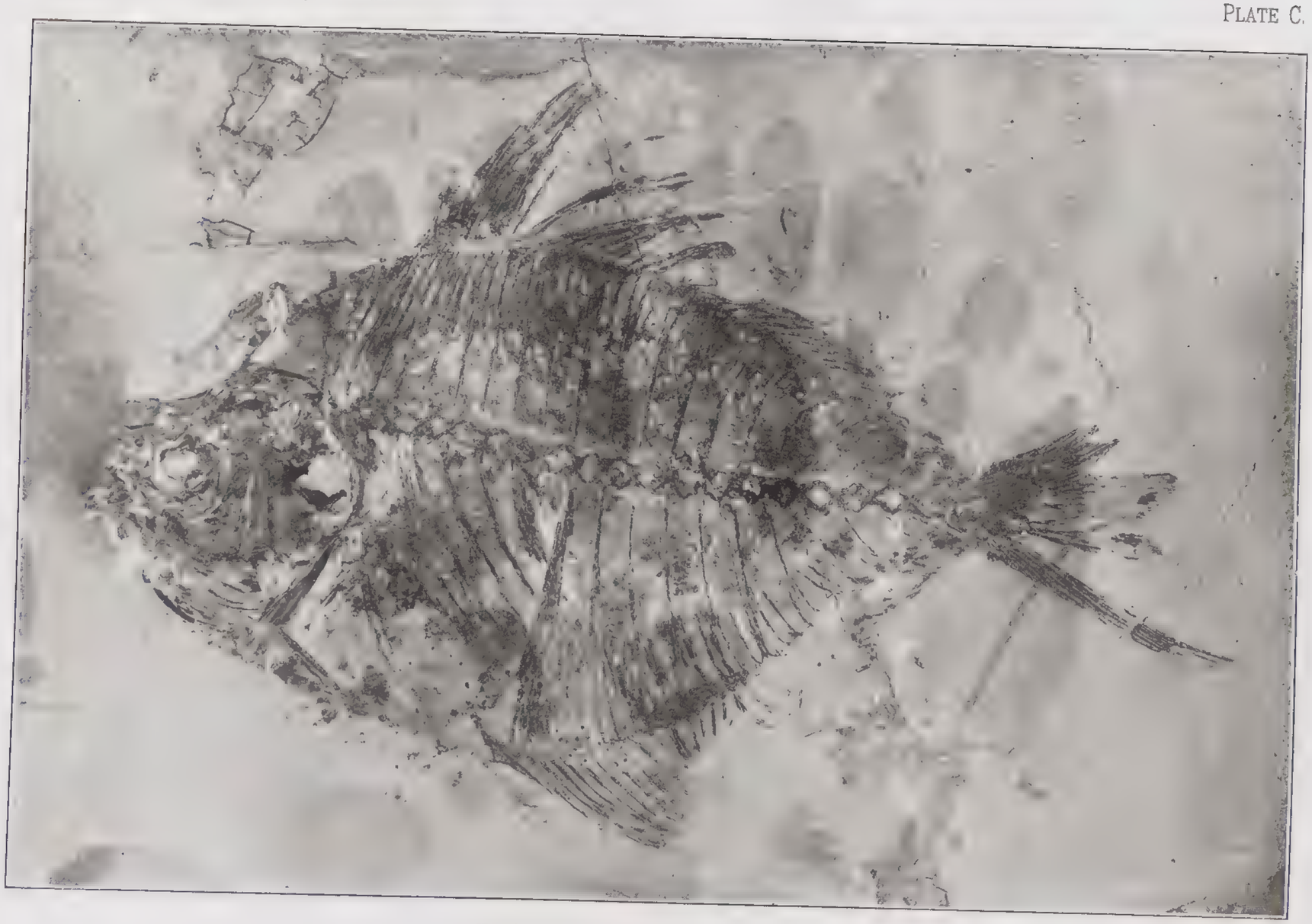
Fig. 3. *Seriola* (*Lichia*) *prisca* (Agassiz). Median fin-rays recumbent. Car. Mus. Cat. No. 4545. ×4/9.



1. *Eocottus veronensis* (VOLTA), figure inverted. $\times \frac{1}{1}$. 2. *Lates gracilis* AGASSIZ, juv. $\times \frac{1}{1}$. 3. *Seriola* (*Lichia*) *prisca* AGASSIZ. Slightly reduced.

Plate C.

Trachynotus cf. tenuiceps Agassiz. A deep-bodied form, perhaps of a distinct species. Car. Mus. Cat. No. 4414. × 1/1.



Trachynotus tenuiceps (?) AGASSIZ. $\times \frac{1}{1}$.

PLATE CI.

Fig. 1. *Callipteryx speciosus* Agassiz. Car. Mus. Cat. No. 4404. ×3/7.

Fig. 2. *Seriola* (*Lichia*) *prisca* (Agassiz). Median fins recumbent. Car. Mus. Cat. No. 4469*a*. ×1/2.

1. *Callipteryx speciosus* AGASSIZ. $\times \frac{1}{2}$. 2. *Seriola* (*Lichia*) *prisca* AGASSIZ. $\times \frac{1}{2}$.

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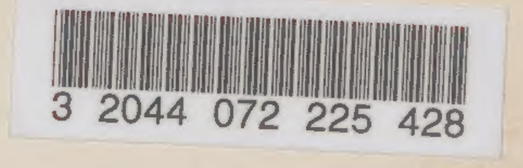
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